PROCEEDINGS

—— OF ——

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

PITTSBURG, PA.

VOL. XIII.

1897.

CONTENTS

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

SEVENTEENTH ANNUAL MEETING.

JANUARY 19th, 1897.

The Seventeenth Annual Meeting of the Engineers' Society of Western Pennsylvania was held in the Lecture Room of the Society, 410 Penn Avenue, Pittsburg, Tuesday evening, January 19th. The meeting was called to order at 8.30; Mr. W. G. Wilkins in the chair, and forty-five members and visitors being present.

The minutes of the last Annual Meeting were read and approved.

Prof. A. E. Frost, Treasurer of the Society, read his Annual Report, which he stated did not include the House Fund.

REPORT OF THE TREASURER.

For the year ending January 19, 1897.

RECEIPTS.

1896, January 17.					
Balance					$ 570 08
Dues to January, 1894.	2			$ 14 00	
" " " 1895,	4			28 00	
" " " "	2	@	$5.00,	10 00	
" " " 1896,	24			168 00	
" " " "	8	@	5.00,	40 00	
" " " 1897,	212			1,484 00	
½ " " ", "	6	@	3.50,	21 00	
" " " "	38	@	5.00,	190 00	
Initiation Fees	31			155 00	

From advertising contracts	271 00	
" sale of Proceedings	39 89	
" rent of rooms in Society's building,	523 00	
Special contribution to Library	3 00	
From Banquet committee	9 58	
Sundries	5 99	
Total	$2,962 46	$3,532 54

EXPENDITURES.

Printing and binding	$ 956 60	
Salaries	630 00	
Rent	1,125 00	
Periodicals	112 75	
Office expenses	212 41	
Stenographic reports	77 92	
Gas, natural and illuminating	71 21	
Water rent	53 50	
Illustrations in Proceedings	43 20	
Expenses of moving	35 00	
Insurance	30 00	
Stereopticon hire	20 00	
Plumbing	15 00	
		$ 3,382 59
Balance		149 95
Total		$ 3,532 54

Respectfully submitted,

A. E. FROST,
Treasurer.

PITTSBURG, PA., January 19, 1897.

The Treasurer upon being asked if he had made any comparison of receipts of dues and initiation fees between the past and previous year, said, that the dues collected in 1895 amounted to $2,158 and the initiation fees $100. In 1896

there were collected for dues $1,955, which shows we fell short about $200 in collection of dues. Initiations are larger this year, being in the aggregate $155 against $100 last year, or 31 against 20.

In the matter of rentals, while it appears that $1,125 have been paid to the agents of this building for 9 months, we have received from undertenants $523, leaving, as my account shows, a net rental of $602, which has been paid by the Society.

There is still, I believe, about $30 due on one of the contracts to the 1st of January, which would leave about $570 in rental for the 9 months, or $760 per-annum.

Mr. Davison remarked that in addition there is the cost of gas and water, which amounted to $124 in 9 months, and furthermore he would call the attention of the Society to the fact that the Treasurer's report shows that the collections fell almost $200 in 1896 below those in 1895, although the membership was greater last year than in 1895; this difference he thought might be attributed to the "hard times."

The Auditing Committee reported that the accounts of Mr. Emil Swensson, Treasurer of the House Fund, and Prof. A. E. Frost, Treasurer of the Society, had been found correct.

Mr. Swensson read the report of the House Fund, which upon motion was accepted and filed.

REPORT OF HOUSE FUND OF THE ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

Paid-up subscriptions to the House Fund of the Engineers' Society of Western Pennsylvania :

Geo. H. Browne	$ 50 00
Thos. H. Johnson	25 00
W. G. Wilkins	50 00
Chas. Davis	10 00
Wm. Metcalf	50 00
H. J. Lewis	10 00
Emil Swensson	10 00

P. T. Berg	10 00
Geo. S. Davison	10 00
Geo. H. Barbour	10 00
H. H. McClintic	10 00
H. H. Rousseau	10 00
W. E. Garrigues	10 00
Chas. Bailey	10 00
J. W. Walker	100 00
J. Kennedy	25 00
I. W. Frank	25 00
Wm. A. Bole	10 00
Karl F. Stahl	10 00
C. J. Rainey	5 00
Chas. Hyde	10 00
Chas. Fitzgerald	10 00
Frans Engstrom	10 00
A. D. Wilkins	10 00
Rob't. Linton	10 00
G. O. Loeffler	10 00
W. C. Temple	50 00
Philo Kemery	5 00
F. Strunz	10 00
G. E. Klingelhofer	15 00
C. B. Connelley	10 00
G. W. Schluederberg	10 00
S. M. Taylor	10 00
Karl von Wagner	10 00
Pierce Brynn	5 00
John Naegeley	5 00
J. M. Camp	10 00
Gus. Kaufman	10 00
Thos. Morrison	25 00
Emil Hallgren	5 00
E. M. Bigelow	25 00
C. E. Lindsay	5 00
H. B. Miller	10 00
A. E. Hunt	50 00
Mary L. Lynne	5 00
O. Sivertsen	5 00
Levi Shook	5 00
E. B. Taylor	10 00
B. F. Jones	50 00
J. A. McConnell	10 00
W. H. Singer	15 00
J. McQuiston	25 00
Geo. Mesta	15 00

Thos. M. McDonald	5 00
J. W. Langley	5 00
F. E. House	10 00
W. L. Scaife	25 00
R. Crooker	10 00
Chester B. Albree	10 00
O. C. Opsion	5 00
F. I. Kimball	2 00
J. K. Lyons	5 00
Dan'l. Ashworth	25 00
Thos. H. Carlin	10 00
Balance of Banquet, 1896	24 42
Receipts from refreshments, opening night	29 00
Back pay on plumbing by property owner	35 15
Total	$1,120 57

Expenditures for work done fitting up house of Engineers' Society of Western Pennsylvania :

Window curtains and shades, Geo. W. Snaman	$ 31 90
Natural gas burners for fire-place, Taylor Burner and E. Co	28 47
House cleaning, M. D. Moody	28 50
Carpets and oilcloth, E. Groetzinger	202 88
Painting and glazing, Frank McComb	72 00
Kalsomining and whitewashing, Bohle & Jones	15 00
Brass sign, J. S. B. Mercer	7 00
Welsbach burners and globes, Welsbach Com'l. Co	59 45
Plumbing, Wm. Klemm & Sons	182 77
Cleaning utensils (paid G. S. Davison), Marshell, Cash Grocer	4 96
Locks and keys, Logan-Gregg Hardware Co	25 10
Chairs, Kaufmann Bros	117 60
Repair of range, Weldon & Kelly	5 00
Carpenter work, Wm. F. Trimble & Sons	89 65
Wall paper and hanging of same, R. M. Kerr & Co	49 74
Glazing, Frank McComb	3 50
Cementing cellar, C. M. Driver	45 00
Repairing sink, Wm. Klemm & Sons	2 25
Diamond brass fire-place, 1st floor, Simpson Gas Appliance Co	9 50
Papering hall, Dewar and Clinton	38 00
Painting hall and stairs, Frank McComb	32 25
Refreshments on opening night, Kuhn, Caterer	60 00
Total	$1,110 52

The Secretary then read his Annual report, which upon motion was also accepted.

SECRETARY'S REPORT.

Mr. President and members of the Engineers' Society of Western Pennsylvania:

Our membership at the date of the last Annual Meeting, January 16, 1896, was..................	415
Forty-four applicants were elected members of the Society during the past year. Of these thirty (30) matriculated..................................	30
Making the total enrollment........................	445
There were eleven (11) resignations, three (3) deaths, and thirty (30) names were dropped from the roll at the last Annual Meeting....................	44
So that our membership at present is...............	401

The average attendance at the monthly meetings during the year was forty-five (45).

Respectively submitted,

DANIEL CARHART,
Secretary.

Reporting for the Board of Direction, the Secretary read a list of names of members recommended by the Board to be dropped from membership. It was moved and seconded that the names read be dropped from the roll in accordance with the recommendation of the Board. Carried.

Mr. Camp, Chairman of the Library Committee, read his report and Mr. McClintic presented the report of the Reception Committee. It was voted that these reports be received and placed on file.

REPORT OF LIBRARY COMMITTEE.

The Society has received during the year from other organizations twenty-seven books and seventy-two periodicals, and there have been added to the Library by binding, eighty volumes. No books have been added by direct purchase.

J. M. CAMP,
Chairman.

The President then read his Annual Address.

PRESIDENT'S ANNUAL ADDRESS.

The close of the Sixteenth year of the Engineers' Society of Western Pennsylvania sees the society one step nearer what many of the older members have long looked forward to, and which they think the size and personnel of the membership should entitle it to, a permanent habitation of its own, and one worthy of the many varied and important interests which the membership of the society represents in this community.

It was only after mature deliberation and much discussion amongst themselves and with other members, that the Board of Direction decided to recommend adversely to the Society the accepting of the proffered quarters in the Pittsburg Carnegie Library Building and to lease the present quarters. It was the almost unanimous opinion that the prosperity and future life of the Society demanded that its headquarters should be in or near the business portion of the city. Most of the members have business interests which compel more or less frequent visits to the business quarters and it was felt that for this reason the present location was a desirable one.

It is the hope and desire of your Board that by the time the lease for our present quarters expires the members will have become convinced that it is absolutely necessary to own our own building, and that the society will have reached such a stage that this can be accomplished, partly by their own efforts and partly by the aid of industries and establishments of the city and vicinity which owe a large share of their financial and business success to the earnest and faithful work of many of their employes who are members of this society.

It is the relation of this society and its members to the business and municipal interests of the community to which I desire especially to call the attention of the members and the public. I believe that this society has to a certain extent been "hiding its light under a bushel" and that the time has come

when casting aside any mock modesty we may possess we should "toot our own horn" a little, and let the public at large know who and what we are, and that we believe the community owes us some recognition, and that, too, of a substantial nature, in return for what we are doing and have done for this community. There is scarcely a manufacturing establishment in the city or its environs, scarcely a railroad entering the city, scarcely a single improvement of a public nature, which has not had connected with it either as engineer, superintendent, or in some other capacity, one or more members of this society. In fact, there is no single body of men which has had such a large share in the upbuilding of this large and prosperous iron, coal and glass center, as the Engineers' Society of Western Pennsylvania. An inspection of the membership roll of this society fully bears out the truth of this assertion.

In the four large bridge works of Pittsburg there are a large number of the members of this society engaged in various capacities from draughtsman up to general manager and proprietor.

In the nine railroads having terminals in the city there are amongst the employes many members of the society serving in the various grades from rodman to chief engineer.

In the various steel works and blast furnaces hereabouts it is safe to assert that they one and all owe the excellence and uniformity of their product to careful and painstaking work of members of the chemical section of the society as a large number of the members occupy the position of chemist to industries of this class.

The public works, such as streets, sewers, bridges and parks of Pittsburg, Allegheny, McKeesport and Braddock and Allegheny County are all executed under the direction of members of this society, and it is very largely to their efforts that the residents of these municipalities have seen the mud roads transformed into well paved streets, bridges take the place of

fords or ferries, and waste ground turned into beautiful parks with walks, drives and green houses for the enjoyment of the poor and rich alike.

In order to emphasize in a more particular manner the relations of this society to the advancement being made by the business and public interests of Western Pennsylvania, a short resumé of the various improvements under way or completed during the year, and with which various members of the society have been connected, will not be out of place.

RAILROADS.

One of the most important enterprises of the year and which, if the promises of the projectors are carried out will have an immense bearing on the commercial welfare of the community, in that its completion will have the result of very largely reducing freight rates to and from Lake Erie ports, is the Butler and Pittsburg R. R. This road is about forty miles in length from Bessemer to Butler, and with the Pittsburg, Shenango and Lake Erie R. R., with which it has been consolidated, forms a through line from Bessemer to Lake Erie. The principal business of the road will be the transportation of iron ore from Conneaut Harbor, on Lake Erie, to the Carnegie blast furnaces at Bessemer and Duquesne. The location of the line, which was made by one of our members, is a remarkably successful one, considering the topography of the country through which it passes. The maximum grade Southbound is only 30 feet to the mile, and the accomplishment of this grade necessitated a very bold location with heavy work, not only in the way of grading, but also of tunnels and bridges, but the purpose of the projectors of the road, a line which could be cheaply operated, warranted the locating engineer in making a location which at first thought might seem inadvisedly expensive.

The magnitude of the work can be better understood by the following figures:

Total excavation, 2,000,000 cubic yards.

Viaducts 17, averaging 700 feet long, one of which, the Bull creek, is 1,400 feet long and 135 feet high

Tunnels 2, one 450 feet long and the other 2,900 feet long.

In addition to the above there is the Allegheny River Bridge referred to in another place.

The engineers, both locating and constructing, are members of this society.

Another important piece of railroad work now going on is the improvement of the Baltimore and Ohio terminals, consisting of the rearrangement of the tracks and yards at the passenger station, and the building of the "Glenwood cut-off." The former improvement includes the building of two miles of new main track and one mile of third track. The original line of the main tracks crossed under Second Avenue near the foot of Fort Pitt incline. The new line follows the river bank under the Tenth Street Bridge, crosses Second Avenue on an overhead bridge, and connects with the former line opposite the Garbage furnace. The improvement necessitates a change of grade and location of Second Avenue, rearrangement of the gas and water pipes, and the building of about 900 feet of double track street railway, all of which is at the expense of the Baltimore and Ohio Railroad Company.

The "Glenwood cut-off" consists of a new line, leaving the present line near Laughlin Station, then crossing Second Avenue at grade and running along the river bank, striking the main tracks again about a half mile east of Glenwood Station. In connection with this improvement is a new yard with a capacity of 2,000 cars. This cut-off will obviate the many vexatious delays to passenger trains caused by blocking the Glenwood yard by freight trains, and also the blocking of street crossings from the same cause. These improvements were designed by and are being constructed by a member of our society.

BRIDGES.

The most important bridge now being built under the direction of members of this society is the Allegheny River Bridge of the Butler and Pittsburg R. R., which consists of:

Viaduct Approach,		1,400 feet.
3 spans 350 feet each,		1,050 "
1 span 500 "		500 "
1 " 180 "		180 "
	Total,	3,130 "

The structure reaches from hill to hill on each side of the river, and crosses both the Allegheny Valley and Western Pennsylvania Railroads and the Allegheny River at a height of 160 feet above the latter, and with the exception of the Ohio Connecting Railroad Bridge is the heaviest piece of railroad bridge construction in this neighborhood.

Another bridge now being built under the superintendence of members of the society is the West Braddock Bridge, across the Monongahela River, which, when completed, will give another electric railroad route between Pittsburg and Braddock, via. the Homestead and Highland R. R. This work consists of a viaduct approach on the Braddock side of the river 900 feet long, one span of 255 feet, one of 518 feet and a third of 491 feet, a total of 2,164 feet.

STREET RAILROADS.

During the past year there have been 50.17 miles of the tracks of the Consolidated Traction Company taken up and relaid in the most substantial manner with 90 pound girder rails, on stone ballast. Of this, 21.65 miles were formerly operated by cables, but are now operated with electricity as a motive power, and during the coming year the last of the cable lines, the Penn Avenue, will be changed to electric.

These lines are at present operated from several power stations, but it is the intention to build a central station at 20th and Railroad Streets capable of operating the entire system of the Consolidated Company. This central station will very largely reduce the cost of operating the system.

The entire work of construction and the operation of the road as well, has been under the superintendence of a member of this society.

WATER WORKS.

One of the most important municipal improvements of the year is the new Allegheny Water Works. The pumping plant is situated at Montrose, on the Western Pennsylvania Railroad, opposite Nine Mile Island. The plant consists of three new compound pumping engines of 12 million gallons capacity each, to which will be added two 7 million gallon engines now at the river Avenue Station, making a combined capacity of 50 million gallons daily. The boiler plant consists of 6 boilers each of 250 H. P. They are internally fired and fed by automatic stokers. The pipe line is a riveted steel pipe 60 inches in diameter and the length from Montrose Station to the Troy Hill Reservoir is 9 miles. This is the largest steel main laid up to the present time, and was laid in seven months. Special machinery was designed for the use of the contractors laying the pipe, in the way of excavators and compressed air riveting and calking machines. The water is taken from the river through a filtering crib sunk below the bed of the river, the size of the crib being 32 feet wide, 8 feet deep and 3,000 feet long. The work was designed and built under the supervision of a member of the society.

The coal storage and handling plant for supplying the boilers with coal was also designed and erected by one of our members.

The city of Pittsburg has also made large additions to its various pumping plants, in the way of new pumping engines, intakes, mains, etc., and will probably during the present year begin the construction of a new reservoir, designed by one of our members, which will add 125 million gallons to the storage capacity.

BLAST FURNACES.

During the past year there have been completed at Duquesne from designs by one of our members, two blast furnaces which are now in blast, and two additional ones are in course of construction, which are the largest blast furnaces in the world. They are 100 feet high, 22 feet diameter in the bosh and 14½ feet diameter in the hearth. The capacity of each furnace is about 570 tons of pig iron daily and the No. 1 furnace has made the unprecedented record of 685 tons in 24 hours. A radical departure in blast furnace construction in the two furnaces now building, is that the number of tuyeres in each will be twenty. Numerous new features in the way of storage bins and machinery for the storing and handling of the ore and limestone have been adopted which will materially reduce the cost of operation.

MANUFACTURING PLANTS.

One of the largest plants built during the year is the new works of the Apollo Iron and Steel Co., situated at Vandergrift, Westmoreland County, Pa., and which, when completed, will be the largest galvanized iron plant in the United States. These works contain the latest and most improved machinery and furnaces for the production of galvanized sheet iron, through all its stages from pig iron to the finished product.

The buildings of the plant comprise a rolling mill 140x800 feet, a converting building 95x1120 feet, and a boiler house 48x260 feet. The Mechanical Engineer of the plant and the engineers of the immense buildings are on the membership roll of this society.

TOWN BUILDING.

An interesting experiment in the way of building a town in which the purchasers of lots receive them with all their improvements ready made, which improvements are usually made years after the town has been laid out, is the town of Vandergrift. The town is situated on the Western Pennsyl-

vania Railroad, forty miles from Pittsburg, and is the site of the works of the Apollo Iron & Steel Co., referred to elsewhere. The design of the town was made by Olmsted, of Olmsted & Eliot, of Boston, and shows a radical departure from the usual plan of laying out a town, in that the streets, instead of being straight and comparatively narrow, are most all on curved lines, and are sixty and eighty feet wide. The land company has graded and paved the streets, laid the sidewalks, planted the shade trees, built water works, and laid all gas and water pipes, built the sewer system and the electric light plant, so that the purchaser of a lot knows that when the purchase price is paid, there will be no further assessments for the sanitary improvements which are so necessary for the health and comfort of the inhabitants.

This method of town building is a radical departure in this vicinity and is an experiment not only financially but sociologically, as the projectors believe that by providing all these improvements at the start, it will bring a better class of workmen to their mills, and that the result will be beneficial not only to the company but also to the workmen and other inhabitants of the town as well.

The engineering work connected with the building of the town was all designed and executed by some of our fellow members.

While there might be mentioned many more engineering works of importance that have been designed or superintended by members of the society, enough has been given to show that the assertion that this society has had a very large and important share in the growth and prosperity of this community, is not to be gainsaid.

It is the belief of the writer that when the proper time comes to present these facts and beliefs to the business and financial interests, they will be met with a proper and fitting recognition, which will aid us in accomplishing the result desired—a building of our own. Until that time arrives we

should take all justifiable means of keeping the aims and purposes of the society before the public, and every member should do his part in the good work by writing and reading papers that will not only be of interest to the members but also to the public as well.

The election of officers for the ensuing year then took place. The President read names of nominees and asked if there were any further nominations.

After it was voted that the nominations be closed, Messrs. Davison and Camp were appointed tellers.

Forty-two (42) ballots were cast and the following named nominees were declared unanimously elected:

For President, one year, Emil Swensson.

For Vice-President, two years, Harry J. Lewis.

For Directors, two years, H. H. McClintic and James M. Camp.

For Secretary, one year, R. A. Fessenden.

For Treasurer, one year, A. E. Frost.

Mr. Emil Swensson, the new President, now took the chair.

Mr. Frans Engstrom offered a resolution that the thanks of the Society be conveyed to Secretary Carhart for his untiring efforts in the interest of the Society during the past three years, which was adopted.

It was moved and seconded that the Annual Meeting adjourn. Carried.

DANIEL CARHART,
Secretary.

REGULAR MEETING.

PITTSBURG, PA., January 19th, 1897.

The regular monthly meeting of the Society was then held, Mr. Swensson in the chair.

The minutes of the last meeting were read and approved.

Reporting for the Board of Direction, the Secretary read the name of one applicant for membership already passed upon by the Board and to be voted on at the next meeting.

There being three candidates for election, viz.: Messrs. W. E. Fohl, J. A. Mohr, and G. D. Marshall; Dr. Stahl and Mr. Lyons were appointed tellers. There were 39 votes cast and the candidates were elected.

Mr. Johnson then read a memorial resolution on the death of Mr. M. J. Becker, and Mr. Wilkins, for the chairman of the committee, read a memorial resolution on the death of Mr. G. W. G. Ferris.

It was moved and seconded that both reports be printed in the Proceedings of the Society, and the motion was carried.

Mr. Wilkins stated that the Society had lost by death another member, viz.: Mr. D. A. Stevenson, and thought it would be proper to appoint a committee to draft a memorial on his death, therefore he moved to that effect, which motion was seconded and carried.

Messrs. L. C. Weldin and Daniel Carhart were appointed as above committee.

Mr. Davison on behalf of the Constitutional Committee, read the proposed revision of the Constitution and By-Laws.

It was moved and seconded that the document be printed and placed in the hands of the members at an early date in order that they might have an opportunity to examine the proposed changes before the next meeting. The motion was carried.

Mr. Fischer on behalf of the committee appointed last January to ascertain the comparative cost of electric and steam power plants, reported that they had made little progress on

account of being unable to get together, but thought that during the coming year some valuable data could be obtained.

Mr. Davison moved that the committee as appointed last January be continued, and suggested that it might be a good idea if the committee would issue a circular to the members of the Society asking them to co-operate in the matter of furnishing data.

Mr. Engstrom offered an amendment to the effect that the Society pay for the printing of the circulars, which amendment Mr. Davison accepted, and the amended motion was as follows:

"That this committee be continued, with the suggestion that they send out circulars of inquiry, not only to persons outside of the Society, but to members, and that the Board of Direction furnish funds for printing these proposed circulars." Carried.

It was moved and seconded and carried that the said committee be empowered to add any member or members to the committee that they may see fit.

The committee appointed some time ago to investigate Mr. Kirk's pavement were not ready to report, but hoped to be able to do so at the next meeting.

Adjourned.

REGINALD A. FESSENDEN,
Secretary.

CHEMICAL SECTION — FIFTH ANNUAL MEETING.

PITTSBURG, PA., January 21st, 1897.

The Fifth Annual Meeting of the Chemical Section of the Engineers' Society of Western Pennsylvania, was held in the rooms of the Society, 410 Penn Avenue, Pittsburg, Thursday evening, January 21st, 1897. Chairman J. M. Camp presided.

The minutes of the last annual meeting were read and approved.

The Secretary reported as follows:

Number of members at last report....	56
Resigned or dropped from membership	2
New members elected in 1896	6
Total membership to date...........	60
Number of meetings held...........	10
Number of papers read.............	10
Average attendance................	15

The retiring Chairman then read a paper on "Blast Furnace Cinders and their Analysis." The paper was prefaced by a few remarks on the encouraging results of the Society's work during the past year and the prospects for the coming year.

BLAST FURNACE CINDERS AND THEIR ANALYSIS.

It is the object of this paper to deal exclusively with the cinder made in furnaces making Bessemer Iron, for the reason that that iron is almost exclusively the product of the furnaces of this region, the largest producers and consumers of the world being found here; and also for the reason that the writer's experience has been particularly confined to that field. On account of the easy solubility of cinders, and the simplicity of the analysis in general, this paper is dedicated to those who know nothing of the subject. In it they will find much that is old and, possibly, some few things that are new.

In the analysis of cinder, like many others, it is of prime importance that the results, to be of service to the furnace manager, be obtained quickly. Consequently, the methods used are those yielding the quickest results with the maximum accuracy, the trifling errors, due to the rapid manipulation, being off-set by variations in each cinder flush, and variations from flush to flush. This difference is due to several causes, chief among which are the following :

1st. Changes in the burthen, due to variations in the weights of ore or flux. 2d. Variations, more or less great, in the ore, flux, or fuel, which the method or time of sampling will not show. 3d. Most important, and ever varying changes, due to the reduction of more or less silica to silicon in the hearth, and its consequent absorption by the iron and loss to the cinder. This latter change is due to the variation in the temperature of the hearth, and may be caused by (1) A reduction of the burthen. (2) Extra coke, or, as is commonly called, a blank charge. (3) To a higher or lower temperature of blast. (4) A slip in the furnace with the resulting introduction of cold stock into the hearth. (5) To a reduction in the volume of air forced into the furnace, with its for a time concentration of heat at the hearth. (6) Changes in the moisture contents of the air. As a consequence of the above changes, sometimes working in unison, and again at variance with each other, the production of cinder within certain close limits, is an unsolved problem. The writer has known one or two instances, when the cinder for two consecutive days showed exactly the same silica, but the laboratory was credited with this fine piece of metallurgical work. In the selection of samples, individual flushes are sometimes analyzed to represent the day's work, put the practice is bad, for the reasons given above, and it is preferable to sample each flush during the day of twenty-four hours. This is usually done by one of the furnace employes, by breaking equal sized

pieces from the test mold samples taken during the day. These samples, properly labeled, are delivered at the laboratory early in the morning, and are there crushed in an iron or steel mortar by the boy to whom this task is allotted, and the entire sample passed through a forty mesh sieve. In case the sample contains iron in the form of shot, these are thrown aside as not being part of the cinder. Only such iron should be shown in the analysis as is present in the form of oxide. Part of the samples, sufficient for the analysis, are then placed in the agate mortar grinding machines, and are there ground till, in the judgment of the analyst, they are sufficiently fine, and the samples, after passing a magnet through them to separate any fine shot iron, are ready for the analysis.

Silica.

In the determination of silica, or as it is commonly called, insoluble residue, on account of the method of analysis, one gram of the sample is weighed off into an eleven centimeter porcelain dish, with watch glass cover; ten cubic centimeters of water are added and the powder stirred up until it is all moistened. Ten cubic centimeters of strong hydrochloric acid are now added, and if the sample contains much iron, a few drops of nitric acid, and the solution still covered, evaporated to dryness over an Argand burner and thoroughly dried. When dry the dish is allowed to cool, and the residue is moistened with about three cubic centimeters of strong hydrochloric acid, and again evaporated to hard dryness. This is an essential point for rapid filtration, as a single evaporation, no matter how well done, does not dehydrate the silica, with the resulting aggravating loss of time in filtering. The dish is again allowed to cool, and the residue taken up with a mixture of twenty cubic centimeters of strong hydrochloric acid and forty cubic centimeters of water. The large amount of hydrochloric acid being added to form ammonium chloride in the subsequent part of the operation. The dish and its contents are heated to near the boiling point for a few minutes, and filtered

through a nine centimeter filter, washed with hot water till free from chlorine, burned and weighed. The native Bessemer ores used at present are practically free from barium, consequently volitization of the silica with hydrofluoric acid is not needed.

The following are some comparative results by the above method, and those obtained by carbonate fusion, solution in water, acidifying with hydrochloric acid, evaporating to dryness, and treating as usual :

Insoluble Residue by Solution.	Silica by Fusion.
No. 1—31.09 per cent.	No. 1—31.29 per cent.
" 2—31.67 "	" 2—31.65 "
" 3—31.55 "	" 3—31.50 "
" 4—30.47 "	" 4—30.50 "
" 5—31.75 "	" 5—31.96 "
" 6—29.38 "	" 6—29.50 "
" 7—30.26 "	" 7—30.37 "
" 8—30.37 "	" 8—30.50 "
" 9—30.74 "	" 9—30.75 "
" 10—31.40 "	" 10—31.34 "

Iron and Alumina.

Alumina.—The filtrate from the silica, in a No. 3 beaker, with watch glass cover, is heated to boiling, and a slight excess of strong ammonia added, and the solution boiled for a few minutes, the beaker is then removed from the light and placed in a cold water bath to cool and for the precipitate to settle. When the precipitate has settled completely, filter by decantation through an eleven centimeter filter, keeping the the paper full until the precipitate is reached, then let the funnel drain and pour the precipitate on the filter with a steady stream until the beaker is drained. Wash with hot water until free from chlorine, burn and weigh as iron and aluminum sesquioxides.

Iron.—Into a No. 2 beaker, without lip and with watch glass cover, there had been previously weighed off one gram

of the original sample; to this was added thirty cubic centimeters of water and twenty cubic centimeters of strong hydrochloric acid and the beaker set on the steam bath to dissolve. This solution is now boiled for a few minutes till all is dissolved, and the hydrogen sulphide all driven off. To this, while still hot, a slight excess of stannous chloride is added (about three drops), as the iron is all present in the ferrous form, and the solution diluted with cold water to about three hundred cubic centimeters. Ten cubic centimeters of the mercuric chloride solution are now added, the solution is stirred, and after waiting one minute, it is titrated with potassium bichromate solution, as previously described before this society.* The iron is reported as iron, but subtracted as sesquioxide from the iron and alumina obtained before.

Lime.

The filtrate from the alumina in a No. 4 beaker is heated to boiling and twenty-five cubic centimeters of a saturated solution of ammonium oxalate added, and ten cubic centimeters of strong ammonia. This is boiled for a few minutes, removed from the light and the precipitate allowed to settle. It is then filtered through an eleven centimeter filter, washed with hot water till free from chlorine, and burned in a muffle furnace, allowed to cool in a dessicator and weighed as lime. The heat of a muffle furnace, at an ordinary red heat, will thoroughly decompose calcium oxalate, for in no case after treating as above, and then heating at the highest temperature of the blast lamp, was there found a greater difference than one to two-tenths of one per cent. In case the cinder is high in magnesia, due to the use of all or part dolomite as a flux, a double precipitation is made of the lime as oxalate.

Magnesia.

The filtrate from the lime, which need not exceed four or five hundred cubic centimeters, in a No. 5 beaker, is cooled

*Transactions Engineers' Society Western Penna., Vol. XI.

by placing it in a cold water bath, and slightly acidulated with hydrochloric acid about five cubic centimeters, and for a cinder containing not over eight per cent. of magnesia, ten cubic centimeters added of a ten per cent. solution of sodium phosphate, and gradually from a measure, with constant stirring, fifty cubic centimeters of strong ammonia. Stir thoroughly and at intervals for two or three hours, then filter, wash with dilute ammonia one ammonia to three water till free from chlorine, burn and weigh.

Manganese.

The behavior of manganese in the furnace is similar to that of silicon. The higher the heat the more of the oxides being reduced and alloying with the iron, and *per contra*, the lower the heat, the less being reduced, and remaining in the cinder. In the method detailed above no attention has been paid to this element, part of the manganese being weighed with the oxide of iron and alumina, and part with the lime. The amount in the cinder is, as a rule, low, and the trifling error introduced, does not affect the metallurgical value of the results. Many determinations have been made by the writer of manganese in the iron and alumina and lime precipitates, as determined above, and in separate samples of the cinder, with the object of finding a rule whereby a certain amount of the total could be deducted from each, but without avail. And in case an accurate, complete analysis is desired, instead of an ammonia precipitation of the iron and alumina, a double basic acetate precipitation must be made, and the manganese precipitated in the united filtrates with bromine, before precipitating the lime. For some time past the writer has been using the colorometric method on cinders, exactly as it is used for the determination of manganese in pig iron and steel, with very satisfactory results.

Herewith are given some comparative results, using the colorometric method and those obtained by the potassa chlorate method :—

Colorometric.		Potassa Chlorate.	
No.	1—.40 per cent.	No.	1—.42 per cent.
"	2—.41 "	"	2—.40 "
"	3—.31 "	"	3—.29 "
"	4—.35 "	"	4—.33 "
"	5—.47 "	"	5—.48 "
"	6—.23 "	"	6—.22 "
"	7—.27 "	"	7—.26 "
"	8—.30 "	"	8—.31 "
"	9—.33 "	"	9—.32 "
"	10—.36 "	"	10—.36 "

Sulphur.

A blast furnace cinder will contain practically all the sulphur of the ore, flux and fuel, less the amount contained in the iron, which amount is dependent on the temperature of the hearth. The higher the temperature the lower the Sulphur, and vice versa. Cinders will vary in sulphur under normal conditions of ore and fuel, from one to two per cent., depending on the proportion of cinder produced to the ton of iron. The determination is effected as follows: Into a dry half-litre flask, introduce about one-half inch, equal to about five grams of chemically pure stick zinc, and then twenty-five-hundredths (.25) gram of the cinder. The flask is provided with a double perforated rubber stopper, through one opening a funnel tube is placed, reaching to the bottom of the flask, and through the other a short piece of glass tubing, bent at right angles, and connected by a short piece of rubber tubing to the delivery tube, also bent at right angles, reaching to the bottom of a one inch by ten inch test tube, into which about ten cubic centimeters of the ammoniacal solution of cadmium chloride is introduced, and the test tube filled about three-fourths full of cold water. Ten cubic centimeters of water are now added to the flask, and gently shaken till the cinder is moistened, to prevent caking on the bottom. The apparatus is connected, and fifty cubic centimeters of dilute hydrochloric

acid added—one acid to two of water. The cinder is dissolved almost instantly, liberating a large volume of hydrogen sulphide.

The compact zinc dissolves more slowly, liberating hydrogen, which gradually displaces the hydrogen sulphide, and carries it over to the absorbent. A gentle heat is applied, which is gradually increased until the zinc is dissolved, and nothing but steam escapes from the delivery tube. The apparatus is then disconnected, and the solution titrated with iodine, using the same solution as is used for the determination of sulphur in iron or steel.

The following are some results as obtained above and those obtained by fusion with the mixed carbonates and nitre, solution, evaporation to dryness, solution, filtering, and precipitating with barium chloride :

Titrating with Iodine. The Evolved Hydrogen Sulphide.		Weighing as Barium Sulphate.	
No. 1—1.55	per cent.	No. 1—1.56	per cent.
" 2—1.65	"	" 2—1.63	"
" 3—1.57	"	" 3—1.59	"
" 4—1.67	"	" 4—1.69	"
" 5—1.58	"	" 5—1.59	"
" 6—1.93	"	" 6—1.96	"
" 7—1.64	"	" 7—1.62	"
" 8—1.80	"	" 8—1.79	"
" 9—1.82	"	" 9—1.83	"
" 10—1.80	"	" 10—1.82	"

Phosphorus.

Phosphorus, under normal conditions of temperature, is practically all reduced in the hearth of the furnace, and there combines with the iron, the amount remaining in the cinder varying from a trace up to two-hundredths of one per cent., the average being much nearer the former than the latter figure. The determination is as follows:

Ten grams of the cinder are weighed off into a twelve centimeter porcelain dish with watch glass cover, and stirred up into a paste with water. Fifty cubic centimeters of strong

hydrochloric acid are now added and two cubic centimeters of nitric acid and the solution evaporated to hard dryness. The dish is allowed to cool and then moistened with about twenty-five cubic centimeters of strong hydrochloric acid, and again evaporated to hard dryness. When cool, from fifteen to twenty cubic centimeters of strong hydrochloric acid are added, sufficient to moisten the residue, and the dish and its contents warmed for a few minutes, and diluted with warm water to about one hundred cubic centimeters. This is filtered through an eleven centimeter filter into a half litre flask, and slightly washed with hot water. To the filtrate a slight excess of strong ammonia is added, about twenty-five cubic centimeters, and then a slight excess of strong nitric acid, and the solution heated to eighty-five degrees centigrade, and seventy-five cubic centimeters of molybdate of ammonia solution blown in by aid of a pipette. The flask is shaken for about five minutes, and the yellow precipitate collected and weighed the same as in ores, pig iron, or steel.

This analysis, like the determination of alkalies, which are ever present in cinders, has no known metallurgical significance, for they are beyond control, and is but rarely if ever done, except for the gratification of idle curiosity, and in a furnace and steel works laboratory so much is wanted that is essential to the proper metallurgical operation of the plant, that scant time is left to curiosity.

The paper was discussed by Messrs. Garrigues, Skinner, Stahl, Handy and others.

The election of officers to serve during the ensuing year being in order, ballots were distributed and the following officers unanimously elected :

Chairman—W. E. Garrigues.
Vice Chairman—K. F. Stahl.
Secretary—A. G. McKenna.
Directors— { F. B. Strunz.
H. S. Menough. }

Annual meeting adjourned.

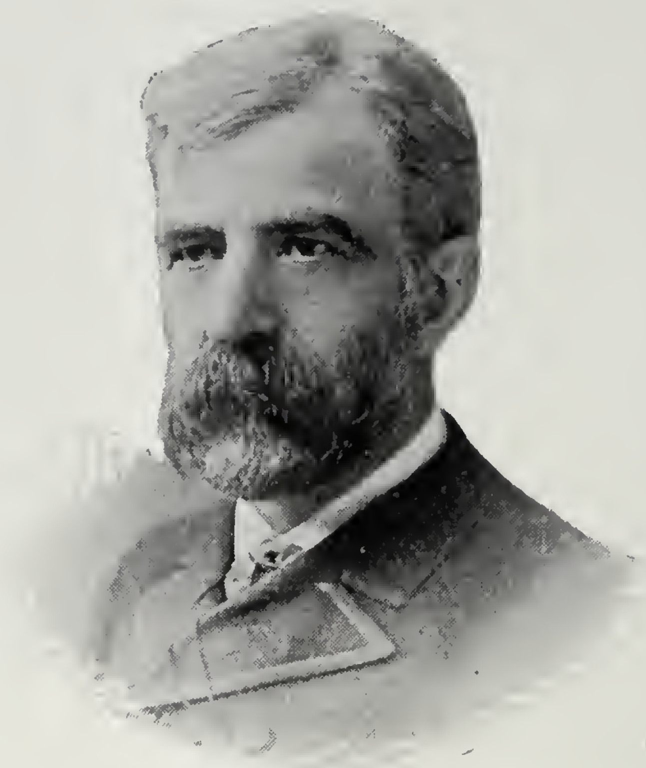
PITTSBURG, PA., January 21st, 1897.

The regular monthly meeting followed the adjournment of the Annual Meeting, W. E. Garrigues, Chairman.

The minutes of the last regular meeting were read and approved. Dr. K. F. Stahl moved that the Board of Directors be requested to have the names of the members of the Chemical Section distinguished in some manner in the list of members at present being prepared for publication. The motion was passed and Mr. J. M. Camp requested to bring the matter before the Board of Direction at its next meeting.

The Section adjourned at 11 P. M.

A. G. McKENNA,
Secretary C. S.



M. J. BECKER.

MEMORIAL ON THE DEATH OF MAX JOSEPH BECKER.

For the third time in the history of this Society, we are called upon to record the loss of a past President, in the death of Max Joseph Becker, who died August 23d, 1896.

He was born at Coblenz, Germany, June 28th, 1828, and was educated in the schools of his native city and at the University of Bonn. After leaving the University, he passed the requisite examinations for admission to service on the Government Railroad Surveys, and in 1848 began his professional career on the Cologne and Minden Railroad, in the capacity of "Engineer's Apprentice" with headquarters at Hamm in Westphalia. This work was interrupted by the Rebellion of 1849, and by reason of his connection therewith he was compelled to leave Germany along with such men as Frederick Hecker, Carl Schurz, Franz Sigel, August Willich, and others, whose enforced exile has been our country's gain.

After a brief sojourn in Switzerland he came to the United States, landing in New York in 1850. His first year's residence in this country was a struggle for a foothold, during which time he engaged in various lines of employment, among others, making surveys in Connecticut for a map publishing house, draughtsman in an engraving establishment, and he even tried his hand at journalism on the staff of the "Abend-zeitung."

In December, 1851, he entered the service of the Steubenville and Indiana Railroad at Stuebenville, Ohio, under Jacob Blickensderfer, Jr., Chief Engineer. His first position with this company was as a draughtsman; but this was soon changed to transitman on location, and then to resident engineer on construction, in which capacity he continued until the completion of the road in 1854.

From 1854 to 1856, he held no salaried position, doing such professional work as offered, and occupying a part of his time in making and publishing a map of Coshocton County, Ohio.

In 1856, he entered the service of the State of Ohio as resident engineer on the Ohio Canal, and continued in that position until 1859.

From 1859 to 1861, he was resident engineer on the Marietta and Cincinnati Railroad in charge of location and construction. During this time he also rebuilt a suspension bridge over the Scioto River at Portsmouth, Ohio, which had been destroyed by the undermining of a tower during a flood.

During the Presidential campaign of 1860, Mr. Becker took a lively interest in the success of the Republican party, and made numerous speeches (in German) in various towns and cities of Southern Ohio, where the German element was strong. In return for this service, Abraham Lincoln commissioned him postmaster at Portsmouth, Ohio. But the drudgery and red tape methods of that office were not suited to his taste, and in 1862 he resigned the office, and again took

service under his former chief, Mr. Blickensderfer, at that time chief engineer of the Pittsburg and Steubenville Railroad, and who placed Mr. Becker in charge of construction of the Steubenville Bridge and its approaches.

In 1863, he again went to the Marietta and Cincinnati Railroad to take charge of the location and construction of its extension from Loveland, Ohio, to Cincinnati. His connection with this railroad company continued until 1867, when he became chief engineer of the Steubenville and Indiana Railroad, which position he continued to fill through all the changes by which the original line has grown and developed into the present system of the Pittsburgh, Cincinnati, Chicago and St. Louis Railway.

In January, 1896, the Board of Directors sought to make his declining years easier, and to that end relieved him of a part of his duties, changing his title to "Consulting Engineer and Real Estate Agent." But the disease, which finally carried him off, had even then laid its hand upon him, and he was not permitted to enjoy the rest from labor contemplated by this act.

His connection with this Society dates from its first organization, he being one of the thirty-two gentlemen present at the first meeting in January, 1880. From that time forward he always took a lively interest in the Society, seldom missed a meeting, and added to the interest and value of the proceedings by his contributions to the discussions of papers read, and especially by his own paper on "Rail Joints," which attracted attention abroad as well as at home. He served the Society on the Board of Direction in 1889 and 1890, and as President in 1893, having the best interests of the Society always at heart, and giving to it the benefit of his mature judgment and ripe experience.

He was also a member of the "Technischer Verein" of Pittsburg, and of the "American Society of Civil Engineers,"

which latter recognized his high standing in the profession by making him its President for the year 1889.

He was a man of kindly and genial disposition, with a ready wit and keen sense of humor, a well trained mind stored with a vast fund of information gleamed not only from his own experience, but from a wide range of general reading; all of which contributed to make him a most delightful companion.

In professional matters, his active and alert mind quickly grasped the essential features of a problem, and lead him promptly to sound conclusions.

Of unflinching integrity, he leaves behind him a long career of official life without stain or blemish. Always devoting his best energies to the interests entrusted to his care, he expected a like faithful service from his subordinates, and while quick to criticize, was also quick to appreciate sincere and honest effort.

In the death of Mr. Becker, this Society has lost an esteemed and valued member; the profession at large, an engineer of representative ability and standing; the world, an honorable and honest man.

Frans Engstrom,
Thos. H. Johnson,
Geo. S. Davison.

MEMORIAL ON THE DEATH OF GEORGE WASHINGTON GALE FERRIS.

The committee appointed to prepare a Memorial on the death of Mr. G. W. G. Ferris, respectfully report as follows:

Mr. George Washington Gale Ferris, Jr., son of G. W. G. and Martha Ferris, was born in Galesburg, Knox County, Ill., February 14th, 1859.

With his parents he moved to Carson City, Nevada, in 1864, and in 1873 went to Oakland, Cal., to attend a military academy, graduating from that place in June, 1876. In September, 1876, he entered the Rensselaer Polytechnic Institute of Troy, N. Y., and graduated in 1881.

For four years thereafter he was engaged in engineering work of various kinds. During the latter part of this period he was employed by the Louisville Bridge Company as mill inspector for the superstructure of the Henderson Bridge. This kind of work was essentially agreeable to him, and he soon became notably proficient in performing the duties required of him. His business tact and ability enabled him to frequently smooth over the differences constantly arising between the mill managers and the Bridge Company.

In April, 1885, he entered the employ of the Kentucky and Indiana Bridge Company to take charge of the testing and inspecting of iron and steel at Pittsburg, Pa., and in 1886 he established the firm of G. W. G. Ferris & Co., Inspecting Engineers at Pittsburg, Pa., associating with him Mr. Jas. C. Hallsted. This partnership lasted until the year 1889, when the firm was re-organized and Mr. D. W. McNaugher and Wm. F. Gronau became partners of the firm.

His work was ably done and his abilities were rapidly recognized throughout the country. He soon succeeded in establishing a large organization for the purpose of conducting all kinds of inspection and testing.

In 1890 Mr. Gustave Kaufman became associated with Ferris & Co., under the firm name of Ferris, Kaufman & Co. This firm was organized for the purpose of engaging in strictly engineering work. Among the structures designed and supervised by them were the bridges across the Ohio River at Wheeling and Cincinnati. Mr. Ferris took an important part in these works. His wonderful ability to cope with financiers was clearly noticeable during the construction of these bridges.

The work from which he received world-wide reputation, was the construction and successful operation of the Great Ferris Wheel at the World's Columbian Exposition. His great financial ability was thoroughly shown in this work, as the necessary funds to construct the wheel had to be raised in the midst of a severe financial depression.

In a financial sense, the Ferris Wheel was not a success for Mr. Ferris. At the close of the World's Fair he was burdened with a large shortage together with the necessity of removing and re-erecting the Wheel.

The accomplishment of these tasks and the carrying of the attendant obligations, under many adverse circumstances and unusual difficulties taxed his powers to the utmost for several years after the close of the Fair. The effort undermined his constitution. Unable to withstand an attack of typhoid fever, which he contracted, he died in Pittsburg on November 22d, 1896.

Mr. Ferris was married to Miss Margaret Ann Beatty at Canton, Ohio, September 18th, 1886.

This memoir would be incomplete without a reference to the peculiar personality of Mr. Ferris. His relations with all with whom he came in contact were at all times cordial and pleasant on account of his affable and gentlemanly manners. He was eminently engaging and social and he had a keen sense of the ludicrous. In all gatherings he at once became

the centre of attraction, having a ready command of language and a constant fund of amusing anecdotes and experiences.

Up to within a few months of his death, he was always bright, hopeful and full of anticipation of good results from all the ventures he had on hand. These feelings he could always impart to whomever he addressed in a most wonderful degree, and therein lay the key note of his success. In most darkened and troubled times—and he had many of these—he was ever looking for the sunshine soon to come.

Both he and his friends were sanguine of the successful outcome of the projects he had on hand, and had he lived he would have been amply repaid for the long struggle which was almost over.

He had, however, miscalculated his powers of endurance, and he died a martyr to his ambition for fame and prominence. By his death, the engineering profession has lost a bright light and a whole souled and charitable member.

GUSTAVE KAUFMAN,
D. W. McNAUGHER.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

The regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Society, 410 Penn Avenue, Pittsburg, Pa., Tuesday evening, February 16th, 1897, the President, Mr. Emil Swensson being in the chair. The meeting was called to order at 8:20, 71 members and visitors being present.

The minutes of the last meeting were read. Mr. W. G. Wilkins stated that he had read the memorial resolution on the death of Mr. G. W. G. Ferris in the absence of the chairman of that committee, and asked that that fact be noted in the minutes. This addition was made, and the minutes approved.

The Secretary read the names of eight applicants for membership already passed upon by the board, and to be voted upon at the next meeting. Ballots were cast for the one candidate for election, Mr. Peter Ferrara, Messrs. Hirsch and Hardy being the tellers. Forty-four votes were cast, and the candidate was declared duly elected.

The committee appointed to draw up a memorial on the death of Mr. Stevenson stated that they were not yet ready to report.

Mr. Diescher, for the Committee on Pavement reported progress, and stated that a final report could not be made for some time to come.

The Committee on Power having no report to make, the Reception Committee was called upon, and Mr. McClintick read the following statement:

Herewith attached is an itemized statement of the Treasurer of the Reception Committee, relative to the last Banquet of the Society held at the Duquesne Club, Feb. 11, which shows

a balance of $3.09 after all bills have been paid. This balance has been turned over to the Treasurer of Society.

Respectfully submitted,

H. H. McClintic,

Chairman.

Report of monies received and disbursed by William Bradford, Treasurer of Banquet Committee, Engineers' Society of Western Pennsylvania, February, 1897:

Credit.

119 tickets sold at $4.00		$476 00

Debit.

Music	$33 00	
Flowers	15 00	
Printing	16 25	
Supper for 100 men, at $3.25	325 00	
Supper for 18 men at $2.50	45 00	
Cigars	20 00	
Refreshments for Musicians	1 50	
Drawings for Menu	9 52	
To Society for Printing	6 00	
Postage	99	
Messengers	65	
Check to Treasurer of Society, to balance	3 09	
		$476 00

It was moved and seconded that the report be received; that the $3.09 mentioned be turned over to the Library Fund of the Engineers' Society, and a vote of thanks be tendered to Mr. McClintick and the other members of the committee.

Mr. Davison—I will agree to that motion except as to where the money is to be turned in. Last year the Reception Committee turned over the amount of $22.00 to the House Fund; they did that two or three times, and the money goes into the hands of the Society and is used for something else. I would make a suggestion that the money be turned into a

special fund—into a Banquet Fund—for this reason, that the last two or three years we have had the hardest work imaginable to stir up enough members to make the banquet a financial success, and it has been hard work to make the receipts come up to the expenses, and it has been suggested that we carry a fund for this purpose so as to relieve this committee from year to year, and in case there be a deficiency we shall not have to go back to the Society or the members individually.

Mr. Wilkins—I move an amendment to that motion, that the surplus be deposited with the Treasurer, to the credit of a Banquet Fund.

Mr. Davison—Suppose that fund should grow large, it would be an inducement to bring out the members. As it is now the parties having the banquet in charge find it hard work to get out whole, and that is the way to bring members out.

It was here suggested that when the time comes that the Society could not get enough members at the banquet to make it a success, it was time to quit.

The President then put the amended motion as follows: "That the report of the Reception Committee be received and filed; that a vote of thanks be tendered the Chairman of the Committee and to the Committee as a whole, and that the money remaining be turned over to the Treasurer, to be placed to the credit of a Banquet Fund." The motion was seconded and carried.

Mr. Davison moved that, since the report of the Committee on Constitution should come in at this point, it be temporarily laid on the table until after the reading of the paper of the evening. The motion was seconded.

Dr. Stahl—I think it would be better to name a special evening on which to take up this matter in order to give the members more time to look it up.

In reply to Dr. Stahl's suggestion it was stated that it was

the idea to go as far ahead as possible, and if there were not time to finish, it could be laid over until another time. The motion was carried.

THE PRESIDENT—"My attention has been called to a bequest of the late Albert Noble, who has bequeathed, I believe, about $10,000,000.00, the interest of which is to be paid out yearly in five prizes to those who do the most valuable work in the different branches specified. I think this body may contain someone willing to try for a prize. The value of each prize is $60,000.00, and there are five of them."

(The Secretary here read the clause of the will pertaining to the above.)

THE PRESIDENT—"Now at least two, if not three, of these prizes are within the reach of engineers, and I think that Pittsburg, with its advancement in certain branches of engineering, will have some men able to compete for them, and I think our worthy Secretary will be glad to assist anybody wishing to try for a prize."

The President was here asked by one of the members if he would not ascertain the exact conditions of the competition, and replied that he would do so.

THE PRESIDENT—I have here a communication from Mr. Flad in regard to a bill providing for work on the Mississippi river, which will in a way affect Pittsburgh, particularly the coal men.

(Action of the Engineers' Club, of St. Louis, read by the Secretary.)

Moved and seconded that the Society concur in and approve of the memorial prepared by the St. Louis Engineers' Club, and that a copy be sent to our Senator and our members of Congress from this district.

MR. DAVISON—I believe Mr. Johnson is posted in this matter, and I would like to hear what he knows about it.

MR. JOHNSON—Mr. President, all I know about it is that I recently saw in some of the newspapers a statement made by

Mr. E. L. Corthell, whom you all know was closely identified with the work of constructing the Ead's Jetties: that an extensive crevasse had occurred near the head of the South Pass, so that a large portion of the volume which should flow through the South Pass has been turned into the Pass a'Loutre, and his communication urged upon the public (and particularly upon Congress) the necessity of immediate attention to the closing of this crevasse. I understand the action of this St. Louis committee goes a little beyond that, and they recommend that Congress devote a part of this proposed appropriation to complete and thorough surveys, with a view to determining the best methods of a permanent solution of the problem. It seems to me that their action is proper, and I am heartily in accord with the motion to join them in their recommendation.

Mr. WILKINS—I understand that their memorial is to make surveys ; it does not carry with it the recommendation for the $250,000.00.

The President then stated the motion before the Society to be as follows : "That the Society as a body heartily concurs in the recommendations of the Club, and that a copy of this motion be forwarded, with copies of the communication from the St. Louis Club, to our Senator and Members of Congress, properly signed and endorsed by the Society, and that notification of our action be sent to the St. Louis Club." The motion was carried.

The Secretary read a communication from Prof. Phillips, Secretary of the Sanitation Committee, during which it was pointed out that the movement owed its origin to a former Secretary of the Society, Mr. Clark, and that as a large part of the work had been done by the Society and its members, it would not be advisable for the Society to withdraw from the movement now. After some discussion regarding this Commission, it was moved that the present committee be continued for the present year, to which motion an amendment

was offered to the effect that the Society pay the annual dues of the members composing the committee. The motion so amended was carried.

Prof. R. T. Stewart here read the paper of the evening, entitled "Some Possibilities of Power Generation by Gas Engines, and the Utilization of Rejected Heat," illustrated by stereopticon views.

SOME POSSIBILITIES OF POWER GENERATION BY GAS ENGINES AND THE UTILIZATION OF REJECTED HEAT.

By Reid T. Stewart.

It will be my purpose to-night to present for your consideration, with the hope of stimulating general discussion, some of the possibilties of power generation by means of the internal combustion engine. Engines of this type have been proposed to run upon almost every conceivable cycle and to consume almost every available fuel. Very few of the numerous attempts, however, to produce a practical internal combustion engine have resulted in success, the difficulties to be overcome being so great that, up to the present time, only gaseous and liquid fuels have given success.

Regarding the action of the internal combustion engine of to-day, although almost every conceivable cycle has been tried, it is a significant fact that, since the lapse of the Otto master patent in 1890 every builder of gas engines of note, so far as I have been able to learn, not already manufacturing such engines, have put upon the market engines running upon either the original Otto cycle or upon a modification of this cycle.

Introductory to my paper proper and for the benefit of those who may not be familiar with the construction and action of the modern gas engine, I have prepared lantern slides showing views of engines, details, etc., which I will now have projected upon the screen.

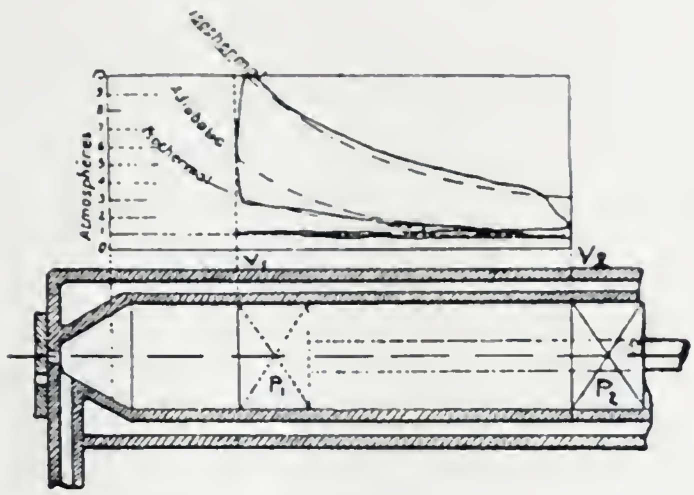


Fig. 1.

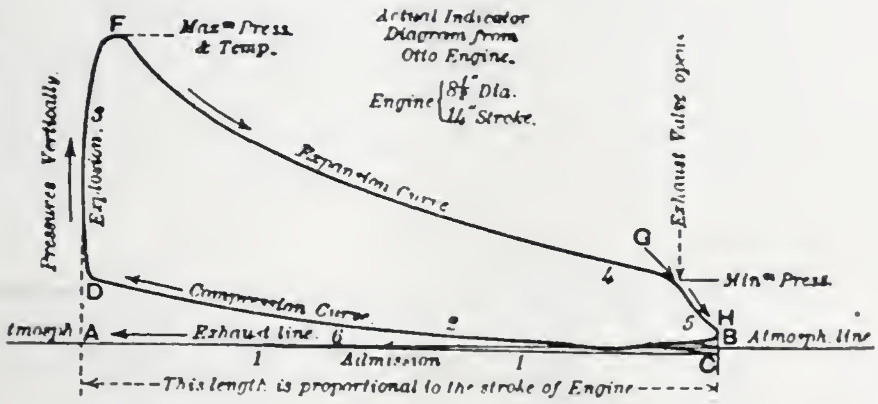


Fig. 2.

CONSTRUCTION AND ACTION.

In Fig. 1 (from Anderson's Conversion of Heat into Work) is shown without details, the cylinder and piston of a gas engine, together with an indicator diagram when working upon the Otto cycle. The action is as follows: At the beginning of the first outward stroke of any cycle the piston is at P_1, and the clearance space to the left is filled with products of combustion at atmospheric pressure left there at the close of the previous cycle. As the piston moves outward it draws in a combustible mixture of air and gas, reaching the end of its stroke at P_2. During the second stroke of the cycle, the piston, returning from position P_2 to P_1, compresses the combustible mixture from volume V_2 to volume V_1. At the end of this stroke the charge is fired and the pressure rises at practically constant volume, as shown by the indicator diagram. During the third stroke of the cycle, the products of combus-

tion expand, doing work upon the piston. At or near the end of this stroke the exhaust valve opens. Finally, during the fourth stroke of the cycle, the products of combustion are expelled, with the exception of what remains in the clearance space.

This is the well-known Otto cycle, and is very clearly shown in Fig. 2 (from Donkin's Gas and Oil Engines), which represents an actual indicator diagram from an Otto engine, with the sequence of operations clearly indicated. Stated briefly, the Otto is a four stroke cycle as follows: gas and air are drawn in on first outward stroke, are compressed into the clearance space on first return stroke, are exploded and expanded on the second outward stroke, and are expelled on the second return stroke.

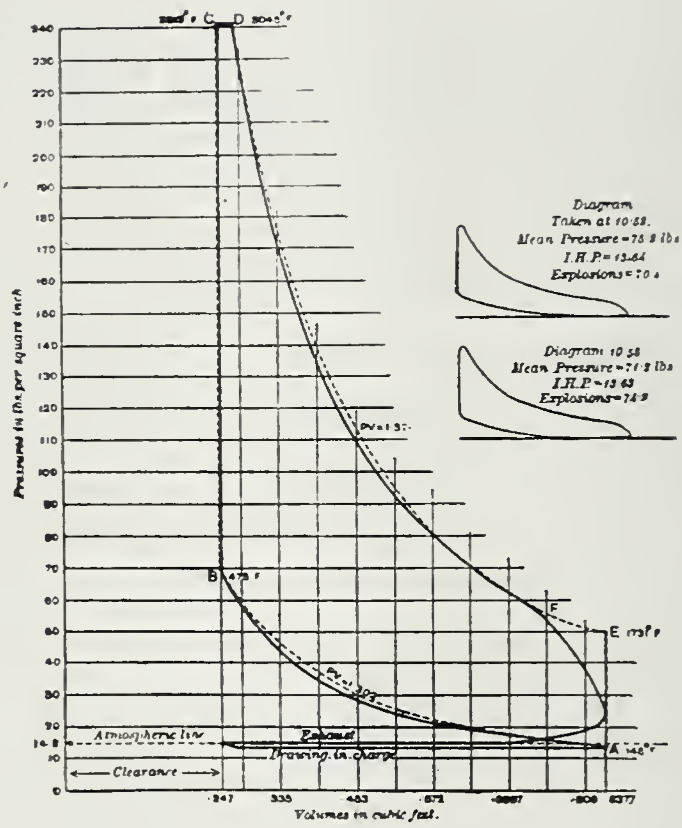


Fig. 3.

Fig. 3 represents another card from an Otto engine, showing pressures, volumes and probable temperatures. Some modifications of this cycle will be noted later in this paper.

The engines being built to-day to run upon the original or a modified Otto cycle are very numerous, their chief differ-

ences being in the details. For many of my illustrations of details I have selected the Crossly Otto engines, made by the Crossly Bros., of Manchester, England, who are probably the leading constructors of gas engines in the world, turning out engines, it is reported, at the rate of about 3,000 per annum.

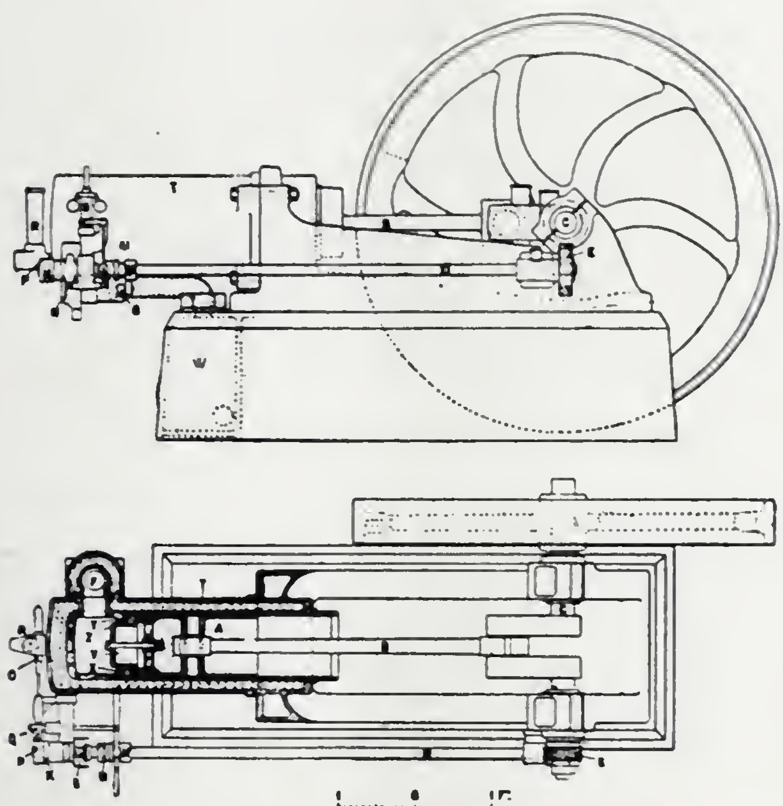


Fig. 4.

Fig. 4 (from Clerk's Gas Engine) shows one of these engines in side elevation and in sectional plan.

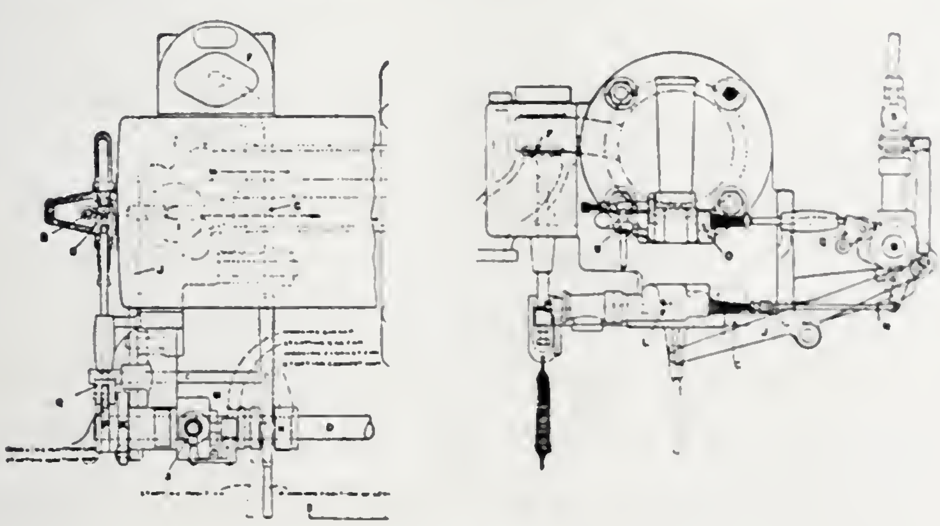


Fig. 5.

Fig. 5 (from Clerk's Gas Engine) shows in detail the means for admitting air and gas, and the manner of governing this engine. I is the inlet valve for both air and gas, and is actuated through lever J by cam K on the lay shaft D. The gas is admitted to the inlet valve I by the valve L, it being actuated through a link and lever by the cam M on the lay shaft. The admission of gas to the cylinder is controlled by the governor S, the governor acting so as to admit either a full charge of gas, or else none, depending upon the speed at which the lay shaft S may be running. Should the lay shaft be running at, or below, the normal speed gas will be admitted to the cylinder every fourth stroke. Should, however, the speed of the lay shaft rise above the normal, then the governor will act so as to prevent the cam from lifting the valve, thus preventing the admission of gas until the speed has become normal. This is known as the "hit and miss" style of governing. The exhaust valve F is actuated through lever C by cam H on the lay shaft. Ignition occurs when a portion of the charge is brought into contact with the incandescent tube R, the time of ignition being controlled by the timing valve O, which is actuated through lever Q by cam P on the lay shaft.

In Fig. 6 (from Clerk's Gas Engine) is shown a Crossly Otto scavenging engine, and in Fig. 7 a scavenging engine for electric lighting. These engines, though operating upon the original Otto cycle, differ in their action from the original Otto engines in this one very important respect, namely, the clearance space at or near the end of the fourth, or exhaust stroke of the cycle, is freed from products of combustion. In the original Otto engine at the same part of the cycle, namely the end of the fourth stroke and the beginning of the first, the clearance space was filled with hot and inert products of combustion, which mingled with the incoming charge of air and gas. In these scavenging engines, Fig. 8 (from Clerk's Gas Engine), the clearance space at the beginning of the first stroke of the cycle is filled with pure and comparatively cool air, the products of

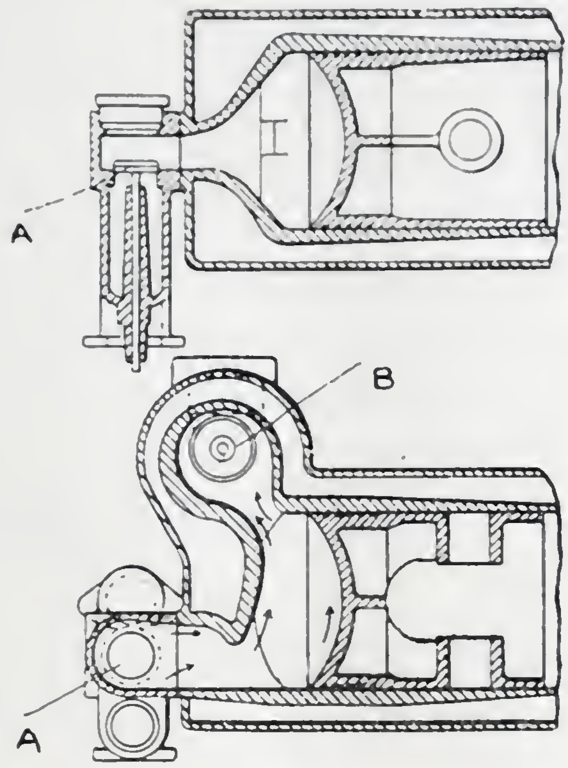


Fig. 8.

combustion having been swept out. This is accomplished by taking advantage of the momentum acquired by the exhaust gases flowing through a moderately long exhaust pipe, the engine being designed, as shown, to permit the free flow of pure air from the inlet A to the exhaust B, the gas admission valve remaining closed during this action.

There are a number of other ways by which this same object my be obtained, and, so far as I have been able to learn, this clearing out of the hot products of combustion from the clearance space, when properly accomplished, has always been attended by good results. It is true, however, that an exhaust pipe may be made so long, or the engine mechanism rendered so complex, in an attempt at improvement in this direction, as to utterly defeat the attainment of the desired object. In order to prevent premature explosions in very large engine cylinders, using high compression, the introduction of scavenging or its equivalent, is rendered almost a necessity.

A type of the modern gas engine that possesses many merits, among which are compactness and greater uniformity of rotative effort, is what might be called the multiple cylinder vertical type. The Raymond Improved Gas Engine, Fig. 9, is

an example of this type. It contains two vertical cylinders resting upon a crank case, and is built in sizes from 6 to 50 B. H. P. Fig. 10 shows a multiple cylinder vertical engine built by the same company, having four cylinders, and furnished in sizes from 60 to 100 B. H. P. Fig. 11 represents an example of the same type of engine, as built at the Otto Gas Engine Works, Philadelphia, in sizes from 4 to 250 H. P., the largest sizes having five cylinders.

The Westinghouse Gas Engine also belongs to this type.

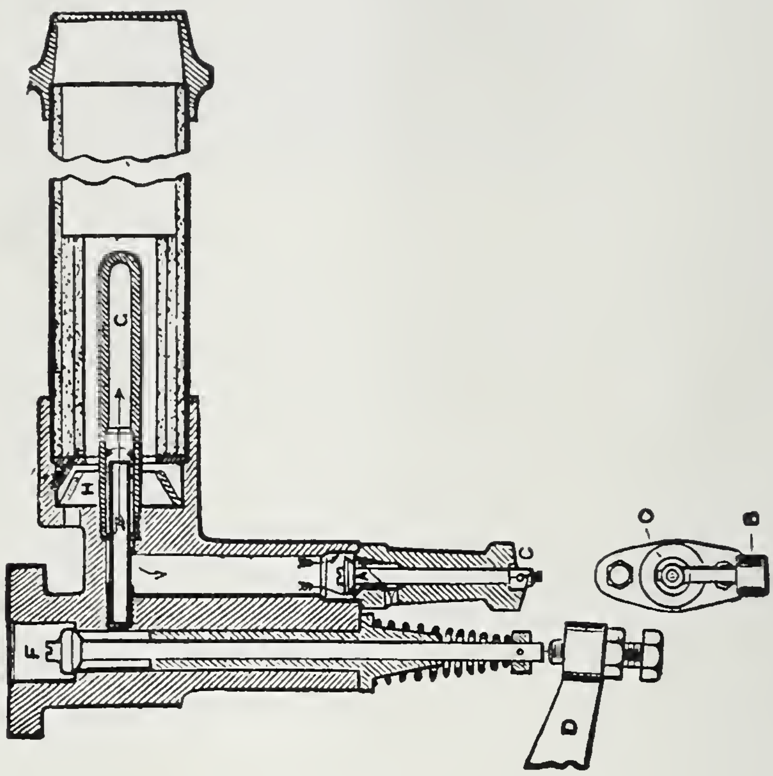


Fig. 12.

IGNITERS AND STARTERS.

The ignition of the charge in modern gas engines is effected chiefly in two ways, namely, by the electric spark and by the hot tube. Of these the latter is the more extensively used. Fig. 12 shows a sectional view of the igniter tube and starting valve of the Stockport Otto engine. G is the igniter tube kept incandescent by a Bunsen flame, not shown. The action is as follows: when the timing valve F opens, at the completion of the compression stroke of the cycle, a portion of the charge rushes into the incandescent tube G, and becoming ignited, carries the flame to the cylinder, thus firing the charge.

This engine is started by placing the crank sufficiently off the center, the tube G having been brought to incandescence, valve A is opened and a combustible mixture of air and gas is allowed to flow into the combustion chamber, expelling the air or other contents of this chamber through the valve A. Upon arriving at the hot tube G, this mixture ignites, thus causing an explosion in the combustion chamber. Should the results of this explosion be sufficient to cause two complete revolutions of the crank shaft, the engine will then receive an impulse in the regular way and will continue to receive an impulse each fourth stroke until the speed for which the governor is set is attained.

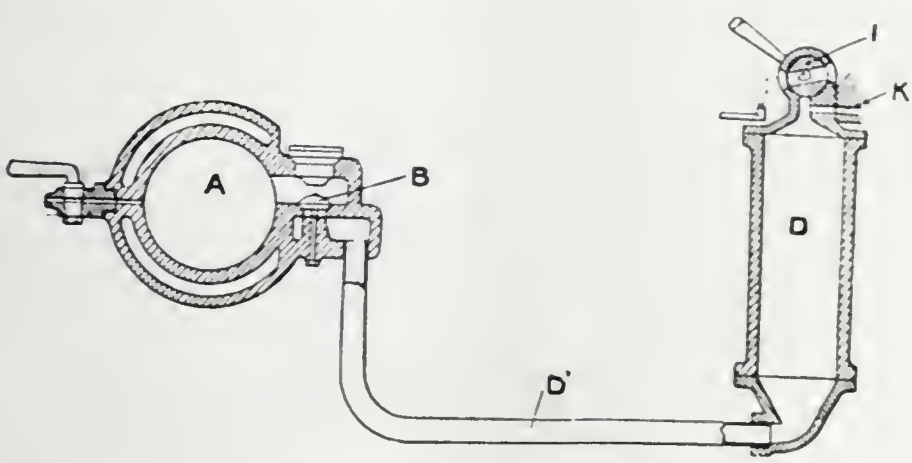


Fig. 13.

In Fig. 13 is shown diagramatically the Clerk flame starter; A being the engine cylinder; B, a check valve opening into the exhaust port; D, a chamber connected to valve B by pipe D′; I, an igniting valve; and K, a port leading to a charging pump. When starting with this gear, the crank, as before, is placed sufficiently off the center, the chamber D, pipe D′, and combustion chamber A of the engine are now filled with a mixture of air and gas at atmospheric pressure, the valve shown at the left being open. This valve and the port K are then closed, the igniter I is operated, inflaming and expanding the mixture at the top of D, thus forcing out the remainder of the mixture and compressing it in the combustion chamber A, where an instant later the charge, now under

pressure, is fired, thus producing a vigorous explosion, which is sufficient to start the engine under a moderate load.

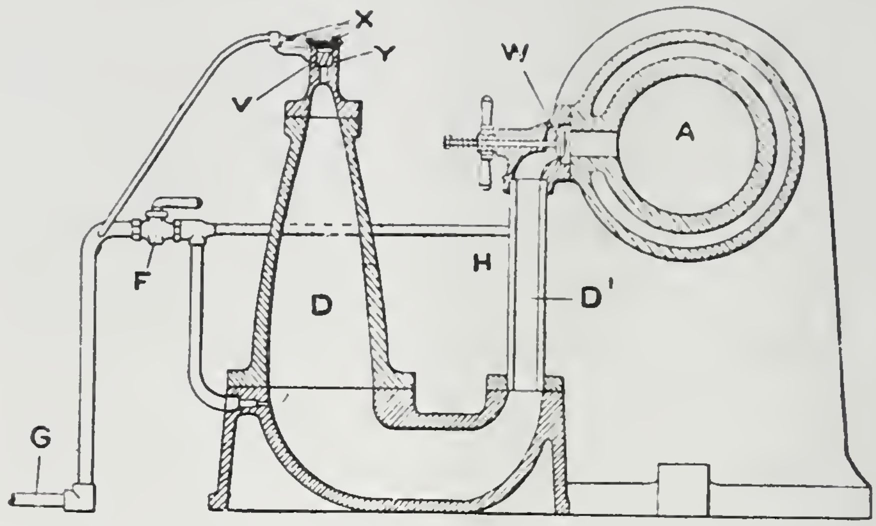


Fig. 14.

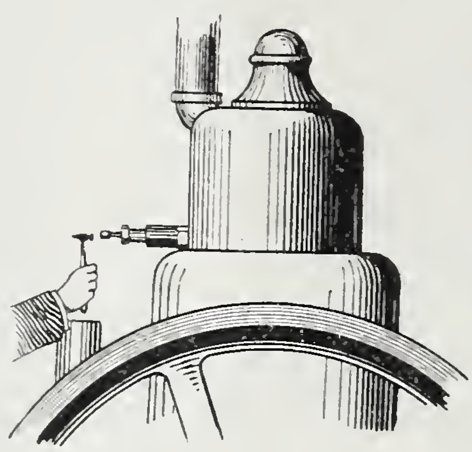
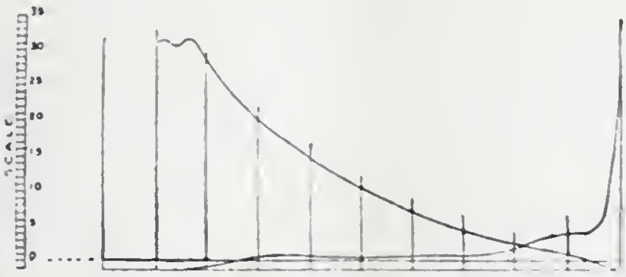


Fig. 15.

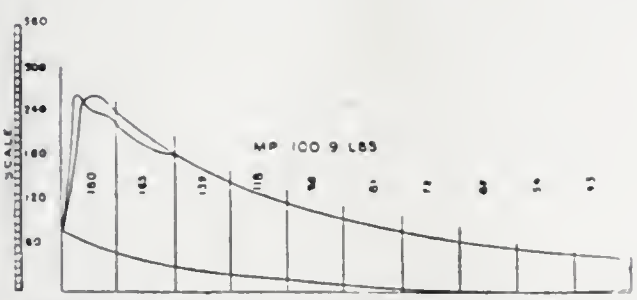
In Fig. 14 is shown an improved form of this starter, known as the Clerk-Lanchester starter. The action is as follows: the crank being in proper position for the start, the spaces D and A containing pure air, the gas valve F is opened, admitting gas simultaneously to spaces D and A. As the gas enters, it mingles with the air contained therein and expels first pure air, then air and gas mingled, through the valve Y. When the mixture being expelled becomes rich enough it is ignited by the flame X and continues to burn, until upon closing the gas valve F the flame strikes back, igniting the mixture at the top of space D; the further action being identical with that shown in Fig. 13, the engine as in that case being started with a compression explosion.

Of the various other methods that are in use for starting gas engines, probably that by the introduction of compressed air to the cylinder is the most effective, as well as convenient, especially for large engines, and where a number of units are installed in the same plant. In Fig. 15 is shown the method of starting adopted by the builders of the Raymond gas engine. The figure is self-explanatory, and is also very suggestive of pent up forces that are about to burst forth. It is claimed for this method, that, in addition to being unique, it is very effective.



Scale of spring, [illegible] per lb.: charging and scavenging diagram: charging diagram of 4 NHP Crossley Otto Engine

Crossley Otto Scavenging Engine (light spring diagram).



Nominal HP, 4; diam. of cylinder, 7"; length of stroke, 15"; rev. per min. 200; indicated HP, 14; consumpt. per IHP per hour, 14.5 cb. ft.; brake HP, 11.97, consumpt. per BHP per hour, 17.0 cb. ft.; mean pressure, 100.9 lbs.; max. pressure, 274 lbs.; pressure before ignition, 87 lbs.; spring, [illegible]"

Fig. 16.

EFFICIENCY AND GOVERNING.

The freeing of the clearance space from products of combustion is attended by excellent results, as may be seen from Fig. 16, which represents an indicator card from a Crossley Otto scavenging engine of about 12 B. H. P. The principal results of a test made by Mr. Clerk upon this engine were reported by him as follows: Diameter of cylinder, 7"; length of stroke, 15"; rev. per min., 200; I. H. P., 14.0; gas per I. H. P. hr.,

14.5 cu. ft.; B. H. P., 11.97 gas per B H. P. hr., 17.0 cu. ft.; mean pressure, 100.9 lbs.; maximum pressure, 274 lbs.; compression pressure, 87 lbs.

The gas used upon this test had a calorific value equivalent to 530,000 ft. lbs. of work per cu. ft. The energy supplied to this engine then was at the rate of 530,000 x 14.5, or 7,685,000 ft. lbs. per H. P. hr., of which amount 33,000 x 60, or 1,980,000 ft. lbs. per H. P. hr. are accounted for by the indicator diagram, thus giving an indicated efficiency of 25.6 per cent., a very excellent showing for so small an engine.

The efficiency of the gas engine has been very materially increased during the last ten or twelve years. For example, the Crossly Otto engine of a certain size, as built in the years 1882, '88 and '94, showed absolute indicated efficiencies of respectively 17, 21 and 25 per cent., the compression pressures being respectively 38, 67 and 88 lbs. This is what should be expected since theoretically, neglecting all losses and imperfect action, the efficiency of this type of engine may be shown to equal unity minus the ratio of the absolute temperature of the charge before compression to the absolute temperature after compression. From this expression it is apparent that an increase in compression is attended by an increase in efficiency.

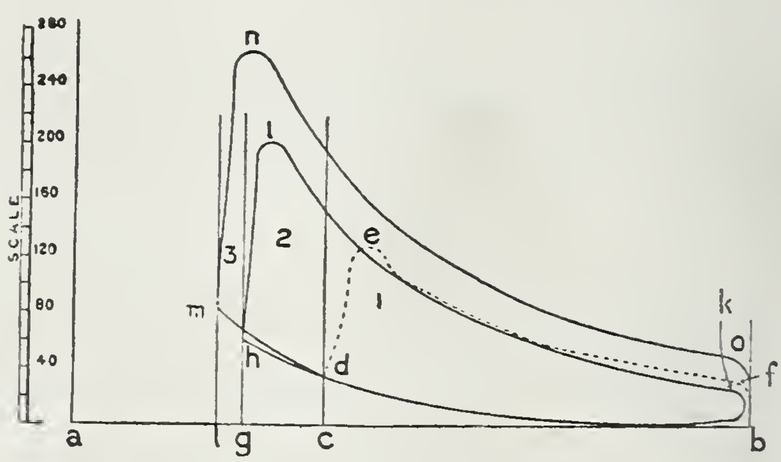


Fig. 17.

This is also very clearly shown in Fig. 17 (from Proc. Inst. C. E., Vol. 124, Pt. 2) representing cards from these three engines plotted to the same scales of pressures and volumes. In this figure, ab represents in each case the volume of the

cylinder at the end of the induction stroke. At the end of the next, or compression stroke, this volume of gases would be compressed to the volumes ac, ag and al respectively, in the engines above referred to as being built in '82, '88 and '94, the corresponding compression pressures cd, gh and lm, being, as stated, 38, 67 and 88 lbs. It will be noticed that the ratio of the area of card No. 2 to the area of No. 1 is greater than that of the corresponding volumes, bg and bc, of the charges drawn into the cylinders of the respective engines. This would imply that more work was done by a certain quantity of gas in No. 2 than in No. 1. It is also apparent that more work would be done by the same quantity of gas in No. 3 than in No. 2. As above stated the absolute indicated efficiencies, obtained by actual trial, were 17, 21 and 25 per cent. In the Hugon engine which admitted and exploded the charge without compression, the efficiency probably did not exceed 5 to 8 per cent. It would appear from these figures then that compression, in this type, is a very essential feature of gas engine economy, and that the high efficiencies of to-day are due chiefly to high compression.

From the report of Mr. Victor A. H. McCowen, of Belfast, of a recent test made by him upon an engine of 120 I. H. P., built by Messrs. Dick, Kerr & Co., I have abstracted the following: The engne tested was a two-cylinder, double acting tandem engine, with cylinders 13.5 and 13.75 by 20 inches stroke, and ran at 160 revolutions per minute, receiving an impulse each stroke. The set of 24 indicator cards, Fig. 18, now shown on the screen, represents what takes place in this engine while working over a range of from 20 per cent. overload to no load. An inspection of these cards reveals the fact that in this gas engine, there is a nice adjustment of work done in the cylinder to the demand for power. It will also be noticed that the compression pressure is maintained constant at all loads, and that for light loads the pressure is well maintained throughout the stroke.

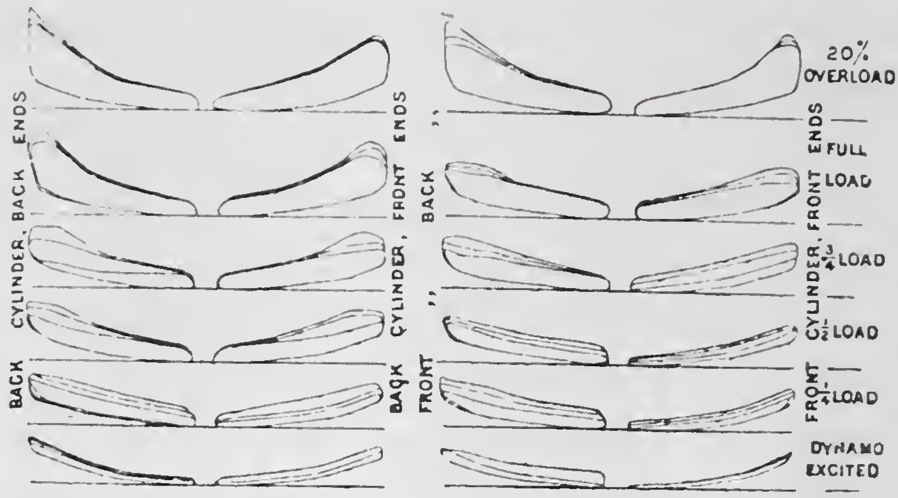


Fig. 18.

The fact that the compression pressure remains constant for all conditions of loading would suggest, as is in fact, the case, that the quantity of air supplied to the cylinder on each induction stroke is always the same. This nice graduation in the impulses then is obtained by varying the quantity of gas admitted to the cylinder. The manner of doing this requires explanation, since, as is well known to those who have had experience with gas engines the proportion of gas in the mixture does not permit of great variation. In this engine, however, as the demand for power gradually decreases, the governor responds by admitting the gas to the cylinder later and later in the charging stroke, the gas even at full power being preceded by a considerable quanity of air. It would appear from these cards that stratification did actually exist in

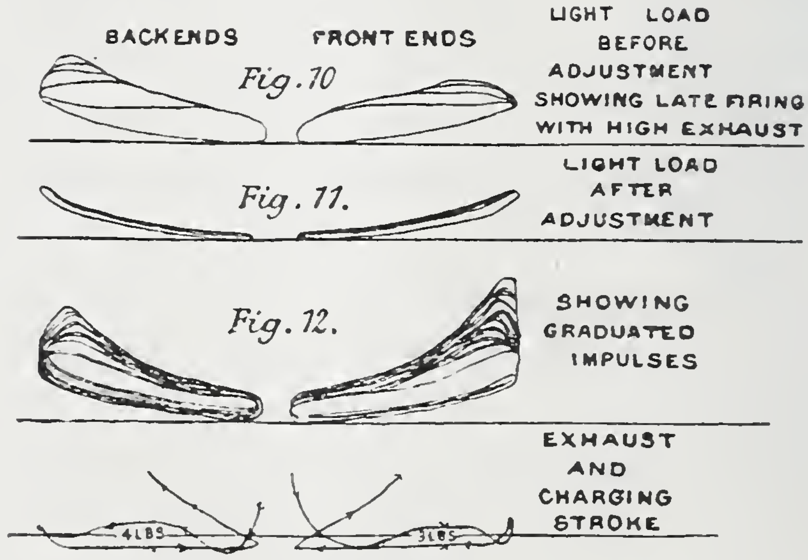


Fig. 19.

the cylinder of this engine, that is, there was at the end of the compression stroke, a portion of rich explosive mixture in the combustion space, the rest of the cylinder being filled with air. In Fig. 19 the card representing "Light load after adjustment," also that "showing graduated impulses," I consider remarkable to be obtained from a gas engine. This engine ran with as great regularity as a double acting simple steam engine. The ignition was by hot tube controlled by a timing valve, and the engine was started by compressed air. In Fig. 20 is shown the principal results of this test, as plotted. An inspection of this figure, if we assume that the gas used was of average calorific power, would reveal the fact that the gas consumption of this engine was too great. This, together with the high price of the gas used, which I believe was about 65 cents per thousand, prevented the engine from competing successfully with steam.

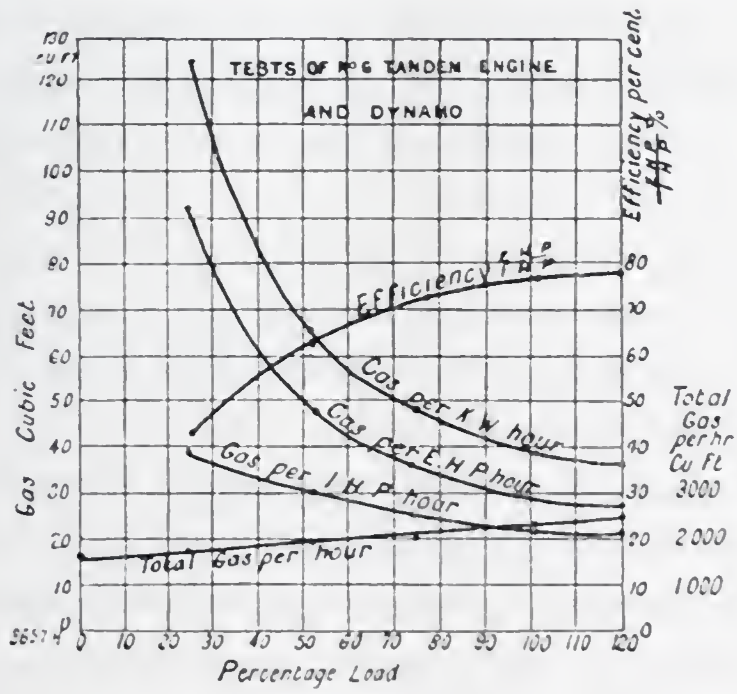


Fig. 20.

UTILIZATION OF WASTE HEAT.

From the results of a number of tests made upon modern gas engines, ranging from 20 to 100 H. P., it would appear that from 72 to 80 per cent. of the heat supplied to the engine is discarded. Neglecting the radiation losses, they being quite small, we can then credit the jacket water and the exhaust gases with carrying off, on the average, about 75 per cent. of the heat supplied to the engine. The discarded heat amounted, by actual test, to 7,400 B. T. U. per I. H. P. hr. in the Crossly Otto engine referred to in this paper, and would probably be 7,200 B. T. U. per I. H. P. hr. in a similar engine of 100 H. P. capacity. Upon this assumption then an engine of 100 I. H. P., while running continuously at full load, would discard to these two sources heat at the rate of 720,000 B. T. U. per hr. Using average values obtained from results of tests upon four engines, I find that of this 720,000 B. T. U., 338,000 would probably pass into the jacket water, and the remaining 382,000 would pass off in the exhaust gases. The temperature of the exhaust gases in this case would probably not be less than 1,700° Fah.

There are a number of ways by which this rejected heat may be utilized, and of these I shall ask you to consider two.

First, by utilizing the rejected heat in the generation of steam for power purposes.

An engine designed with this object in view could be arranged so as to utilize practically all the heat lost to the jacket water and, by properly proportioning the heating surface of the steam generator, the greater part of the heat resident in the exhaust gases could also be withdrawn. Assuming that the steam is to be generated at a pressure of 100 lbs. gauge, the feed water being at a temperature of 185° Fah., it would require 1,100 B. T. U. to generate one pound of steam. The temperature of saturated steam at the assumed pressure being 338° Fah., it would be practicable to reduce the temperature of the exhaust gases to say 550° Fah. We could therefore

abstract sufficient heat from these gases to reduce their temperature by 1,150° Fah. Assuming the specific heat of these gases to remain constant over this range of temperature, which is practically the case, we can easily deduce that 68 per cent. of the heat contained in the products of combustion can be abstracted. The total amount of heat available then in an engine of 100 I. H. P. would be approximately, neglecting radiation losses, 338,000 plus 68 per cent. of 382,000, or 598,000 B. T. U. per hr. Deducting 10 per cent. for radiation losses, we get as a net result 540,000 B. T. U. per hr.

This amount of heat would, under the assumed conditions, generate steam at the rate of 490 lbs. per hr. From this we can see that the I. H. P. of a single 100 H. P. gas engine could be increased by about 10 to 12 per cent. This small gain in power would not be a proper return for the extra outlay and trouble involved. If, however, the plant were large enough to warrant the installation of a compound condensing engine, this increase in power might reach under favorable conditions as much as 30 or even 35 per cent. I believe that an installation of this sort would, for plants of 1,000 H. P. or over, prove to be economical in the generation of power, especially in localities where fuel is expensive. Since the steam engine, in this case, could not be governed in any of the usual ways, it would be necessary to connect it in some manner to one of the gas engine units. The best arrangement doubtless would be to have one or more of the gas engine units constructed as a steam gas engine, with the steam and gas cylinders arranged tandem, or at least connected to the same crank shaft. This would be a perfectly practicable arrangement, and should not be confounded with any of the various methods that have been tried, but without success, of introducing the steam into the gas engine cylinder.

I am aware that it might be difficult to maintain, when running under the above conditions, proper lubrication within the cylinders of gas engines as now built, but I believe that this could be overcome.

Second, by utilizing the discarded heat for warming buildings, drying, cooking, etc. In shops, factories, office buildings, hotels, restaurants, laundries, etc., the waste heat from gas engines could be used in most instances to greater advantage than that from steam engines.

For general warming purposes I believe that a hot water system would, in most cases, be the best to install. It would possess the advantage of being applicable to gas engines as now built without necessitating any change in the engines proper, besides being safe, convenient and economical. The arrangement that I have in mind is as follows: The main return from the hot water heating system is connected to the engine at or near the bottom of the water jacket. The top of the water jacket is connected directly to a heater, through which the exhaust from the engine is made to pass, the heater being connected to the main flow pipe of the hot water heating system.

The action would be as follows: The water from the main return of the heating system entering the engine jacket at say 110° Fah., would leave at a temperature of say 135°, carrying with it the heat ordinarily rejected to the water jacket. It would then enter the heater at a temperature of 135° and leave at say 165°, having reduced the temperature of the exhaust gases to say 300° which would be practicable in a well-designed heater. This of course presupposes the rapid circulation that is so desirable in most hot water heating systems.

Assuming, as before, that the temperature of the exhaust gases is 1,700° Fah., it would be practicable to abstract enough heat to lower their temperature 1,700° minus 300°, or 1,400°. Under favorable conditions then we could abstract 82 per cent. of the heat ordinarily rejected in the exhaust gases. The total amount of heat available for heating purposes then in an engine of 100 H. P. capacity running at full load, deducting 8 per cent. for radiation losses, would be at the rate of 600,000 B. T. U. per hour.

From the reports of the U. S. Signal Service, it would

appear that the mean temperature at Pittsburg for the months of November, December, January, February and March, are respectively 40, 31, 29, 31 and 39 degrees, making an average, for the five coldest months, of 34° Fah.

Using the formula $h=(nC/55+G+W/4)t$, in which C is the cubic contents of the room or building, W, the area of exposed wall, G, the area of glass, n, the number of changes of air per hour, t, the difference between inside and outside temperatures, and h, the number of heat units required per hour; I get by substituting average values obtained from a recently constructed business block, the formula $C=14h/t$.

The rejected heat from the 100 I. H. P. engine considered would then, while running under full load, maintain a temperature of 70° within a building having a volume of $C=14\times 600{,}000/(70-34)=233{,}000$ cu. ft., or a floor space of about 20,000 sq. ft., the temperature without being the mean obtained for the five coldest months at Pittsburg. In an office building this same engine would furnish sufficient heat, under the above conditions, for 58 rooms, the rooms having an average volume of 4,000 cu. ft. For zero temperature outside, however, and 70° within, the volume heated would be reduced to 120,000 cu. ft., or in the office building considered to 30 rooms, leaving 28 rooms to be heated from some other source. On the other hand, when the temperature rose above 34° some of the rejected heat would have to go to waste.

If this same engine be placed in a building having a volume of 480,000 cu. ft., it would furnish enough heat to maintain a temperature of 70° within, when the temperature without was 52°; while for zero temperature, it would furnish but one-fourth the heat required. It would then be necessary to place one or more additional heaters in circuit between the engine heater and the main flow pipe of the hot water system. For the mean temperature at Pittsburg, during the five coldest months, this engine would furnish a trifle over 50% of the heat necessary.

As a check upon these results, I have compared them with those obtained by Mr. John H. Mills, for the Pierce Building, Boston, during the month of December, 1888. The average temperature for that month was practically the same as the average temperature used by me in the above computations. The Pierce Building has a volume of about 500,000 cu. ft., and was heated during the month cited, by a hot water system combined with a steam system, arranged so as to utilize the exhaust steam from the pumps and engines. The average heat required, during that month, as reported by Mr. Mills, was at the rate of 751,000 B. T. U. per hour. In this building, at the time of the test, the halls and unoccupied rooms were maintained at a temperature of 50° and the remainder of the building at 70°, the average external temperature for the month being about 32° Fah. It would appear from these figures that the gas engine considered in this paper, had it been installed and operated under the assumed conditions, would have furnished, on the average, 80% of the heat necessary for December of that year. This would show that my estimate of 50% for a building of substantially the same size and character, heated under practically the same conditions, is, as it was intended to be, somewhat conservative.

I am well aware of the fact that in buildings of the character considered, there is ordinarily, during the day, a demand for but a small fraction of 100 H. P. But the demand for this amount of power could be easily created through the business portions of our cities. What I refer to is the placing at convenient locations, in the basement of such buildings as could best utilize the discarded heat from gas engines, plants of from say 50 to 500 H. P. capacity, such plants to furnish power for the elevators, printing presses, etc., located within a convenient radius. For such service, with hydraulic transmission arranged with provision for a moderate storage, the load upon the engines could be kept practically constant during the business hours of the day. This would permit of the

engines working at their maximum efficiencies, and, at the same time, would furnish the rejected heat with regularity for utilization; both of which are eminently desirable features. Another great advantage of such a system would be the small cost of transmission, or rather distribution, of the power.

This proposed method of utilizing the waste heat from gas engines would also be well adapted to shops, factories, laundries, in fact to any building in which both power and heat are required.

COST OF POWER.

The best modern gas engines of from 50 to 100 H. P., running at full load, will show a heat consumption, when using illuminating gas of average composition, of 10,000 B. T. U. per I. H. P. hr., or 11,500 per B. H. P. hr. If we take as average values for illuminating and natural gases, respectively, 675 and 1,000 B. T. U. per cu. ft., we get the gas consumption per H P. hr. as follows: first, for illuminating gas per I. H. P. hr., 14.8 cu. ft., and per B. H. P. hr., 17.0 cu. ft.; second, for natural gas per I. H. P. hr, 10.0 cu. ft., and per B. H. P. hr., 11.5 cu. ft.

I have been informed by the Pittsburg representative of a leading gas engine builder, that from their experience, it would appear that the indicated work obtained from the use of these two gases is not in proportion to their respective heating values; that, whereas the average heating value of natural gas is about 50 per cent. greater than that of illuminating gas, the indicated work per cu. ft., as compared with that of illuminating gas, was found, in a number of instances, to be from but 5 to 10 per cent. greater. As no determinations were made for the calorific values of the gases used upon these trials, I am inclined to believe that the heating values of the gases may not have been up to the average, or that the best proportion of gas to air was not used. Perhaps someone, during the discussion for this paper, may be able to furnish some valuable information bearing upon this matter. However,

in order to be upon perfectly safe ground, I have assumed, as a basis for my estimates, instead of the 11.5 cu. ft. obtained, 16 cu. ft. of natural gas per B. H. P. hr.

My estimate for the cost of 100 B. H. P. for 309 days of 10 hours each, allowing the rejected heat to go to waste, is as follows:

Interest on cost of plant, $3,500 at 6%	$210 00	
Depreciation and repairs, at 7 %	245 00	
4,944 thousand ft. nat. gas at 15c, net	741 60	
Attendance, ¼ time at $2.50 per day .	193 13	
Supplies	120 00	
Total cost of 100 B. H. P. per annum		$1,509 73

This is at the rate of $15.10 per B. H. P. per annum, upon the supposition that the engine runs at full power for 309 days of 10 hours each.

Running upon the same service, but at one-half load, assuming that the thermodynamic efficiency remains constant, which would be practically the case for an engine governed by the hit and miss method, and also assuming a mechanical efficiency of 87 per cent., I get as follows:

Interest on cost of plant, $3,500 at 6%	$210 00	
Depreciation and repairs at 6½ %	227 50	
2,794 thousand ft. nat. gas at 15c, net	419 10	
Attendance, ¼ time at $2.50 per day..	193 13	
Supplies	100 00	
Total cost of 50 B. H. P. per annum		$1,149 73
Cost per B. H. P. per annum of 309 days of 10 hours...........		$ 22 99

Running upon the same service, but at one-fourth load, the cost of 25 B. H. P. would be as follows:

Interest on cost of plant, \$3,500 at 6% .	\$210 00	
Depreciation and repairs at 6 %	210 00	
1,718 thousand ft. nat. gas at 20c. . .	257 70	
Attendance, $\frac{1}{4}$ time at \$2.50 per day .	193 13	
Supplies	90 00	
Total cost of 25 B. H. P. per annum		\$ 960 83
Cost per B. H. P. per annum, 309 days of 10 hours		\$ 38 43

Assuming that this engine runs under a load that varies from 25 to 100 B. H. P., so that the summation of the time intervals at intermediate points are practically equal, then the cost per B. H. P. per annum would be \$25.51.

In these estimates no rental charge for space has been entered, because of the fact that an engine of 100 H. P., of the vertical multiple cylinder type, would require a floor space of not more than 5x8 feet, and could be placed in the least valuable part of the basement. Probably twice this area would be necessary for the same engine directly connected to a generator or to pumps, although a more compact arrangement could be had if desired. In any case, if a rental charge for space is to be made, it should be quite small per H. P. per annum.

No charge was entered for jacket water supply, because when utilizing the rejected heat, and when not utilizing this heat, the jacket water could be cooled by being circulated through a tank, or cooling coils, located on the roof, or at other convenient place outside of the building. This could be accomplished, for average conditions, at an extra cost of about 45 cents per brake H. P. per annum, which is of course, quite insignificant.

My estimates then for the cost of power, when generated by gas engine units of 100 B. H. P., located in the basements

of suitable business buildings of Pittsburg and Allegheny, would be, for natural gas and upon the basis of 309 days of 10 hours, as follows:

1.	When running at full load	$ 15 55
2.	When running at one-half load	23 44
3.	When running at one-fourth load	38 88
4.	When running at from $\frac{1}{4}$ to full load	25 96

Should the rejected heat be utilized for heating purposes, in the manner that has been proposed in this paper, no extra expense of consequence for installation need be incurred, since the cost of the apparatus necessary to abstract heat from the exhaust gases would be practically offset by the reduction in cost of the other heating apparatus.

I shall make no attempt in this paper, as to do so would make it unduly long, to estimate the value of the rejected heat when utilized in the various ways suggested. The amount of heat, however, that could be utilized for heating purposes, at pratically no expense, may be deduced from what has been given, and would be as follows:

		B. T. U. per hr.
1.	Engine of 100 B. H. P., at full power	690,000
2.	" " " " at one-half power	391,000
3.	" " " " at one-fourth power	240,000
4.	" " " " at $\frac{1}{4}$ to full power	440,000

Using the formula derived for average conditions, namely, G=14h\t, I get, by substituting the proper values given for Pittsburg, the following for the cu. ft. of space that could be heated, when the temperature without is the average for the five coldest months:

		Cu. ft. of space.
1.	Engine of 100 B. H. P., at full power	269,000
2.	" " " at one-half power	152,000
3.	" " " at one-fourth power	94,000
4.	" " " at $\frac{1}{4}$ to full power	172,000

In an office building this engine would, for the average winter temperature at Pittsburg, supply heat to respectively 67, 38, 23 and 43 rooms, having an average contents of 4,000 cu. ft., the temperature of the rooms being maintained at 70°; while in a similar building having a volume of 500,000 cu. ft., it would, under the same conditions, furnish respectively 54, 30, 19 and 34% of the heat required.

Aside from the utilization of the rejected heat, my figures, which I believe are substantially correct for the best conditions, would show that power can be generated by gas engines in isolated plants, where natural gas is available at present prices, at from one-third to one-fourth what it would cost to deliver the same power by a central station system using steam generators and electric, hydraulic or pneumatic transmission.

Mr. Davison suggested that as the subject was an important one, and there were several other things to consider that evening, amongst them the revised Constitution, the discussion of this paper be postponed until the next meeting.

Mr. Bole—There is an unusually large attendance here this evening, and it is a question as to whether the same is due to the discussion of the new Constitution or the gas engine. I think we should discuss that which brings the greatest number of members out, and we can only ascertain that by taking a vote. If it be the gas engine, I think we should have papers on that about twice a month.

Moved and seconded that the discussion of the paper be proceeded with. Carried.

Mr. Diescher—I did not notice in the reading of the paper whether it stated that the service consisted of 365 days at 24 hours per day, or 300 days at 10 hours per day.

A Member—The paper mentions 309 days at 10 hours per day.

Mr. Diescher—The production of an annual horse-power by a gas engine, according to the figures given by Pro-

fessor Stewart, does not appear to be economical, at least not in the Pittsburg region. Here good coal is delivered on factory sidings at $1.00 per ton. Considering an ordinary Corliss engine requiring 30 pounds of steam per hour per horse-power, and five pounds of coal to generate this quantity of steam, a horse power in 300 working days at ten hours per day requires 300x10x5=15,000 pounds of coal, which is seven and a half tons, and this at a dollar a ton amounts to $7.50, or not much over one-half the lowest cost of an annual horse-power as mentioned by Prof. Stewart with respect to the gas engine.

Prof. Fessenden—I think that figure is very low. I would like to know if there is a steam plant in Pittsburg that producers a horse-power at anything less than $30 per horse-power per year. If I could learn of any place where it is claimed, I would like to verify it.

Mr. Diescher—Well, 30 pounds of steam per hour per horse-power is the standard amount established by the Centennial Commission, and will develop one horse-power in any well designed, automatic cut-off engine, such as a Corliss engine. This result will be attained without compounding. As to the quantity of coal, 5 pounds, per horse-power per hour, I have to say that it is a liberal allowance since one pound of coal easily generates 6 pounds of steam of 80 pounds of guage pressure, even with boilers absorbing not over 60 per cent. of the heat developed by the fuel. I assume Pittsburg coal containing about 14,000 heat units.

The President—Referring to the remarks of Prof. Fessenden, he would like to know of a steam plant in Pittsburg that can produce one H. P. per annum for less than $30, running 309 days at 10 hours per day. These figures say 17 pounds of steam on a full load, or 25 pounds on a half load, and so on. He believes you cannot produce one HP. per year for less than $30. That is the disputed point; who can tell how much steam costs?

Prof. Stewart—I would like to call Mr. Diescher's at-

tention to the fact that I made a comparison of isolated gas engine plants with a central station system, using steam power and electric or other transmission; and if I have been properly informed, the cost of coal would not constitute, for such a system located at Pittsburg, more than from 5 to 10% of the total cost of delivery of power by that system, to one of our business blocks. If this be the case, the cost of power delivered by such a system, would not be materially lessened were the fuel to be had at no cost.

Not long since Mr. L. B. Stilwell read before this Society, a paper upon the possibilities of electric transmission and distribution of power at Pittsburg. In that paper he estimated that the consumer would, for power purposes, have to be charged for current alone at the rate of $50.00 per HP. per annum. In addition to this charge, the consumer would have to install, at his own expense, the necessary transformers and motors at a cost, as estimated by Mr. Stilwell, of $3,000 for a 100 HP. plant. Interest on cost of plant, depreciation, supplies, attendance, etc., would increase this to say $60 per HP. per annum, as compared with my estimate of $15.10 for an isolated gas engine plant of 100 HP., running under full load.

THE PRESIDENT—I would like to ask Prof. Stewart what he means by ¼ estimated attendance?

PROF. STEWART—Attendance of one man ¼ of the time.

THE PRESIDENT—For ¼ time work those figures would be very low.

PROF. STEWART—The man should have other duties that would require ¾ of his time and you do not require the services of an engineer, as any good mechanic can learn to start, look after and stop a gas engine.

A member here mentioned a Raymond gas engine in use in La Fayette, Ind., the man running it also attending to a small planer. This was a 6 brake HP. engine, 1,980 feet per day, 10 hours per day. The member did not know whether the cost of natural gas was as low as 5 cents per thousand there

or not, but thought it was. So that this was 2,000 feet per day or 10c per day for a 6 brake HP. engine, and the man who ran it merely started it in the morning; saw that there was sufficient oil to lubricate the machinery, and kept almost continuously at his planer. The engine was started by an explosion from a common brass shell, such as used in a shotgun, the same being about ½ full of powder.

Mr. Bole—I am a builder of both gas engines and steam engines, and therefore cannot afford to let either one be disparaged for the benefit of the other; therefore, the question of which is the more suitable depends largely upon the conditions surrounding the case. It depends largely upon the amount of power required, the time when it is required, and whether it is to be used continuously or intermittently.

In a case of producing small horse-powers there is no question but that the gas engine is more economical than the steam engine and its boiler. In other words, if power is wanted in large quantities, such as the case of rolling mills, where coal is cheap, it is a pretty even thing, in my opinion, as to the cost of fuel between one engine and the other.

Mr. Diescher, in his argument deals only with the cost of fuel, while Prof. Stewart has taken into consideration the management and running expenses, as well as the fuel, which is a very different thing.

In regard to the question of cost of fuel, I would say that when coal in this city is put up as a mark, it is a very difficult matter to produce a gas engine, or any other similar apparatus to do work more cheaply than can be done by good boilers and good engines.

I will place on the board a few figures which, in my opinion, will be a fair statement of the comparison. As a member of your committee appointed for the purpose of ascertaining the cost of power, this matter is of considerable interest to me and also of considerable importance to all of us. The whole thing can be referred back to a few fundamental assumptions

which can be proven by data, which are widely known by those familiar with the performance of steam engines and gas engines.

(Here Mr. Bole placed the following table on the blackboard and explained his reasons for taking these figures):

GAS ENGINES.	STEAM ENGINE.
Assume that a good gas engine of 50 HP. or thereabouts can produce a Brake HP for	Assume that Pittsburg slack coal will evaporate per lb. of such coal
$12\frac{1}{2}$ cu. ft. per hour	6 lbs. of water
10 hours per day	Assume that a good 50 HP. steam engine will develop a HP. in
125 cu. ft. gas per HP. pr hr	30 lbs. of steam per hr.
300 days in yearly service	Then 5 " slack coal pr HP. pr hr
37.500 cu. ft. per HP. pr. yr	10 hrs per day
10 cts cost of nat gas pr M	50 lbs. slack per HP. per day
$3.75 full cost pr HP. pr yr.	300 working days per year
	15,000 lbs. coal per HP. per yr
	$\frac{15000}{2000}$ equal $7\frac{1}{2}$ tons per yr.
	Slack can be bought for 50c per ton in Pittsburg, thus costing
	$7\frac{1}{2}$ x 50c or $3.75 per HP. per year as cost of fuel.

Mr. Davison—I would like to have Mr. Bole put another column on the board; supposing the natural gas to be used under a boiler to generate steam, how would that compare in cost per horse power?

Mr. Bole—If you have to pay for gas to burn under the boiler, then at the rate of 8c or 10c per thousand you will find that this slack coal at 50c per ton will evaporate more water to the dollar's worth than gas will do, the ratio would certainly be 2 to 1, and perhaps more.

Mr. Davison—Can you give the amount of gas per horsepower per hour when the gas is used to produce steam?

Mr. Bole—In 1890 I made some tests of a locomotive boiler, using natural gas fuel, and these tests showed a consumption of 2.56 cu. ft. of gas per pound of water evaporated. On the same basis as the foregoing the following equation shows

a terrific cost of gas, which can perhaps be partially explained by the fact that a locomotive boiler is about the worst kind of boiler for such fuel, viz:

$$\frac{2\frac{56}{100} \times 30 \times 10 \times 300 \times 10}{1,000} \text{ equal } 23\tfrac{4}{100} \text{ per HP. per year.}$$

Mr. Brashear—At one time after running my boiler with \$1.55 slack I thought I would try natural gas by meter and after a three days' run I used \$4.95 worth against \$1.25 worth of coal for the same time.

Prof. Fessenden—I would like to ask Mr. Bole whether the comparison he has made in the table is quite fair. The gas engine is assumed to take $12\frac{1}{2}$ feet of gas and the steam engine 30 lbs. of steam. Now this is a very high efficiency for a gas engine, 20 to 30 feet being more usual, and I have never heard of any engine taking as low as 10 feet. On the other hand, two engines have been built which take less than ten pounds of steam, and there are engines on the market guaranteed to take only 13 lbs. It seems to me that we ought to compare the 13 lb. steam engine with the $12\frac{1}{2}$ ft. gas engine.

Mr. Bole—In answer to the question of Prof. Fessenden, I might say that records have been made on duty tests of the most favorable sort, as low as $1\frac{1}{2}$ lbs. of coal per *indicated* HP. developed by the engine. But such cases are exceptional, and cannot be used in comparison with everyday practices. Such engines are always of large horse power, are compound, triple expansion, or even quadruple expansion, have steam jackets, high boiler pressures and exhaust into vacuum. They are run at most favorable loads by specially trained experts and using the very best quality of coal. If I admit that 5 lbs. of slack coal is liberal and might be reduced somewhat, I must also claim that 50 cents per ton for slack coal in a manufacturing city is very low, and might as properly be increased, thus keeping the total cost about as I have shown it.

The gas engine retains much of its economy in the smaller sizes, whereas the steam engine grows much more wasteful in the smaller sizes. The gas engine is peculiarly fitted for such

installations as require power intermittently, and where frequent stoppages are made. When the gas engine stops the expense ceases, but with the steam boiler it is necessary to burn coal to keep steam up, even though the engine itself be stopped. The cost of banking fires over night, firing up preparatory to starting, etc., etc., make the gas engine easily lead in economy for such work as requires the intermittent use of power in small quantities.

The dangers of boiler explosions, cost of pumps for feed water, and the steam required to operate them, cost of boilers, stacks and furnaces, might be mentioned as additional factors in the case.

Mr. Davison—It might be interesting to know what can be done with artificial gas in comparison with natural gas. I had occasion to look up several gas engines recently and found two makers of gas engines who were not willing to guarantee the natural gas consumption, but would guarantee on artificial gas. They had each made very extensive tests on the engines, which we will say were about 2 brake HP. or 50 indicated HP. One of the tests was made in the east and another in the northwest, and the average result of these tests was 21 cubic feet of artificial gas per indicated horse-power. This would mean about 30 cu. ft. of gas per brake HP. per hour. For 10 hours per day and for 300 days with gas at $1.00 per thousand, this engine will cost $90.00 per HP. per annum, as compared with Mr. Boles' figures.

After some further remarks by Messrs. Le Pontois, Bole and Stewart, concerning the merits of natural and artificial gas, during which it was pointed out that natural gas did not appear to have the advantages in power per cubic foot that it should have theoretically from its greater heat of combustion, it was voted that a special meeting be called March 2d, to consider the new Constitution, and that the discussion of Prof. Stewart's paper be postponed till the next regular meeting of the Society, and the meeting then adjourned.

CHEMICAL SECTION.

PITTSBURG, PA., Feb. 18, 1897.

The regular monthly meeting of the Chemical Section was held in the rooms of the Society, Feb. 18th, 1897. W. E. Garrigues in the chair; 18 members were present. The minutes of the last regular meeting were read and approved.

J. M. Camp reported that in the forthcoming list of members of the Society, the profession of each member would be designated.

The Chairman appointed the following committees: On Sanitation, to take effect in March, Chairman F. C. Phillips, K. F. Stahl, J. M. Camp. On Chemical Literature: Chairman J. O. Handy, Geo. O. Loeffler, Walter Riddle, Wm. Coster, F. T. Aschman.

Mr. J. O. Handy then read the paper of the evening, on Sand Filtration.

SAND FILTRATION OF A PUBLIC WATER SUPPLY.

A RESUME OF REASONS FOR FILTRATION AND AN ACCOUNT OF WORK DONE WITH AN EXPERIMENTAL FILTER PLANT AT CRAIG STREET, PITTSBURG, FROM SEPTEMBER 22D, 1895, TO SEPTEMBER 24TH, 1896.

BY JAMES OTIS HANDY, CHIEF CHEMIST OF THE PITTSBURG TESTING LABORATORY, LIMITED.

For the convenience of those who may wish to refer to only a part of the data contained in this paper, a summary is now given.

SUMMARY.

1. *The Transmission of Certain Diseases by Drinking Water.*—The most important cases of transmission of cholera and typhoid fever by this means are reviewed.

2. *The Purification of Infected Drinking Water.*—The most conspicuous instances of the prevention of disease transmission by the filtration of public water supplies are given. Page 10.

3. *The Filtration of Public Water Supplies.*—Essential features of the Artificial or Slow Sand Filtration System and of. the Mechanical Systems. Page 12.

4. *The Craig Street Experiment in Sand Filtration.*—

(a).—The origin and growth of the idea. Pages 16-17.

(b).—The construction of the tank and filter house. Pages 17-18.

Pages 19-47 (c).—The record of a year's work.

(1). Tables showing amount of water filtered, the number of tests made and the average results obtained. Pages 51-52.

(2). Tables showing in detail the bacterial results of each of the nine runs. Pages 53-65.

(3). Explanatory notes in diary form. Pages 21-47.

(4). Tables showing in parallel columns, bacteria, river heights and typhoid cases in Pittsburgh at corresponding periods. Pages 66-81.

(5). A table showing the bacterial and chemical composition of the raw and filtered waters at corresponding periods. Pages 82-83.

(6). Effect of acid culture medium in restraining the growth of certain kinds of bacteria. A strong indication of the absence of typhoid bacilli from the filtered water. Pages 48-49.

(7). Relative number of gelatine liquefying colonies in the raw and filtered waters at corresponding periods. A second piece of evidence that the bacteria passing through the filter are common water bacteria. Page 50.

(8). A few experiments with a culture of the Typhoid Bacillus. It is shown that it will grow in the culture media

used for the filter control work and at the ordinary temperatures. Page 49B.

(9). A test in which a large number of bacteria of the species bacillus prodigiosus were fed into the filter with the raw water. They appeared in greatly diminished numbers in the filtered water, nine days later when the sand was scraped. As this bacillus is similar to that of typhoid fever, its retention by the sand is interesting. Page 49A.

(10). Methods used in bacteriological control work. Pages 84-88.

(11). Cost of the Craig street filter. A financial statement. Pages 89-93.

1. Drinking Water as a Carrier of Disease.—This matter has been so thoroughly investigated and talked about that I may be offending the propriety of the occasion by mentioning it. It seems to me, however, that it is a logical and necessary preface to my paper, and I therefore entreat your patience for a few moments while I pass in review a few of the facts which have settled beyond dispute, the carriage of typhoid fever and cholera by drinking water.

CHOLERA

In 1854 there was a cholera epidemic in Pittsburg: 1,000 persons died in ten days. These persons had nothing in common but the public water supply. In 1873 cholera came again but was confined to four persons living down the Ohio river, two miles *below our water intake.*

The city of Glasgow, while introducing Loch Katrine water, was invaded by cholera. The contrast between the progress of the disease in the districts having the old and those having the new water supply was very marked.

In 1866, while cholera was abroad, one of the London water companies, although expressly forbidden to supply anything but filtered water, *did* send through its pipes the unfil-

tered water of the river Lea. There was an outburst of cholera all along its mains. Since 1874 the London water companies have been under strict supervision and the city has practically escaped cholera. Even in 1892, although quarantine against Hamburg was not maintained by England, no community with a protected water supply received infection.

In 1892 cholera, traveling westward through Germany, found only Hamburg with an unprotected water supply. It suffered for the 14th time in 60 years. There were 17,975 cases and 7,611 deaths. Altona, adjacent to and below Hamburg on the river Elbe, with a water supply which in its unfiltered state was more vile than that of Hamburg, escaped infection because of the efficiency of its sand filters. The Imperial Board of Health has since forbidden German water companies to furnish unfiltered river waters.

Turning from cholera with its almost theatrical method of destroying human life to typhoid fever with its matter-of-fact ways, it will be apparent that it is transmitted through drinking water just in the way that cholera is.

TYPHOID FEVER.

Vienna, in 1874, introduced a water supply from the mountains. The typhoid death rate fell from a maximum of 30 per 1,000 to 1.11. In 1879, the old supply of Danube water was introduced temporarily into Vienna. A typhoid epidemic followed.

Paris has two supplies: springs and the river Seine. In 1889, the first source falling short, Seine water was substituted. Three weeks later, (the natural interval), typhoid fever prevailed.

Munich and Frankfort-on-Main were affected with typhoid fever until they adopted purer water supplies.

In Lowell, in 1890, of 457 persons having typhoid fever, only one drank well water exclusively, ninety-one drank both well and river water. and the other 365 drank only river water.

An epidemic of typhoid fever in St. Louis in 1892 was nearly confined to the part of the city supplied with river water. The majority of the houses were in good sanitary condition. (A blow for the then already tottering "sewer gas" theory.)

In Plymouth, Pa., in 1885, and in Worthing, Eng., in 1893, over 1,000 cases of typhoid fever came from single cases through water supplies. In the first instance the infectious matter had been frozen up all winter, and passed with the spring floods into a reservoir. In Over Darwin, Eng., 2,000 cases of typhoid fever are said to have come from one case.

Newburyport, in 1892-3, had an epidemic of typhoid fever following the temporary use of Merrimac River water. The infection came by river from Lowell, 25 miles above.

The Kensington district in Philadelphia was until 1889 supplied by direct pumping from the Delaware River at a point just below the junction of a very foul creek. Although only containing one-fifth of the city's population, it yielded one-half of the typhoid fever deaths in Philadelphia. In 1889, the Kensington pumping station was abandoned and the district was thereafter supplied from the East Park Reservoir, a a large one holding several days' supply and therefore allowing the water to improve by subsidence. Not only the typhoid but the general death rate in the Kensington district fell at once with the introduction of the new water supply.—"Typhoid Fever in Philadelphia," by Henry Leffmann, M. D., in the "Dietetic and Hygienic Gazette," October, 1896.

2. *The Purification of Infected Water by Sand Filtration.*—From the instances above cited, the fact that drinking water is the chief vehicle for transmitting cholera and typhoid fever can no longer remain in doubt. We are now most interested in ascertaining how drinking water can be prevented from performing this disagreeable office for which it is so preëminently fitted.

For an intelligent grappling with the problem of rendering infected water harmless, it is necessary to understand that typhoid fever and cholera are produced by germs whose life period, size and other characters are now well known.

The bacillus of typhoid fever, for example, will live for a long time in the dry state. In excrement on the earth it will live for many months even in freezing weather. In water it will live for a week or two. It does not, however, multiply in water. A single case of typhoid fever produces germs enough to infect a large stream. The rates of flow of the Allegheny river and its tributaries are such that we are exposed to infection from cases occurring more than 100 miles above us. Our reservoir never has over two days' supply, and it has frequently less. There is therefore little purification by sedimentation.

Although this typhoid bacillus is very small, it has size, and it may be removed from water by filtration along with other suspended matters.

In Europe, sand filters have been in successful use for many years. Altona, by the use of filters prevented its drinking water from bringing cholera in 1892, despite the fact that it drew its water from the Elbe river below the Hamburg sewers.

Hamburg has insured itself against the recurrence of its 1892 experience by the adoption of sand filters. The filters are proving to be more than a cholera barrier, for in Hamburg in 1894, the typhoid fever and general death rates were lower than ever known. Instead of 100 to 400 typhoid deaths per year, they had only 47 in 1894.

Zürich reduced its typhoid death rate by sand filtration and was in 1895 improving it still further by embodying in its filtering arrangements an increased area and a lower rate of filtering.

Lawrence, Mass., adopted sand filtration in 1893. Frequent typhoid epidemics had occurred before. None have come

since that time and none are expected. In 1865 there were only 13 deaths up to November, and of these several were mill operatives who drank raw river water.

Poughkeepsie, N. Y., with sand filters in use for years, has had very little typhoid fever. St. Johnsbury, Vt., has been equally fortunate for the same reason. Hudson, N. Y., Mt. Vernon and Ilion, N. Y.; Ashland, Wis.; Far Rockaway, L. I.; Somersworth, N. H.; Grand Forks, N. D., and Lambertsville, N. J., are all using the system of sand filtration so successfully used in Europe.

There are in the United States a total of 270 water works using filtration as a means of getting a public water supply. There are *1,320 other* cities and towns having water supplies so clean that filtration is unnecessary. There are only 138 public water works which are at all analagous to that of Pittsburg (I do not mention Allegheny because it is a long way on the road toward a proper water supply). These 138 cities and towns (only *three* of which have a greater population than Pittsburg), pump from rivers or creeks to reservoirs and thence to consumers. This brings out a little more clearly our position in the matter of water supply. It has long been known that we were distinguished for excessive typhoid mortality. With Lawrence out of the race, and Allegheny preparing to withdraw, there may be doubts in the minds of some as to who will lead, but there is none in mine.

3. *Filtration of Public Water Supplies.*—It has been truly said that "all filtration is sand filtration" The difference between systems is one of speed. Some follow what the report of the Pittsburg Sand Filtration Commission calls "the old English or the now somewhat ancient method of securing purification of water supplies," but which I would prefer to call the well-tried and reliable, or even the ancient and honorable method of banishing typhoid fever and shutting out Asiatic cholera. This is the unpatented European or slow sand filtration system. Water is filtered usually after settling

for a few days through filter beds containing 3 to 4 feet of sand, held up by gravel and broken stone. The daily rate of filtration is from 2,000,000 to 3,000,000 gallons for each acre of filter bed. In exceedingly cold places the filter beds have to be arched over. They have not been in Poughkeepsie nor in Lawrence and they would not have to be in Pittsburg.

The mechanical systems of filtration either force or allow the water to pass through sand in tanks at rates often 100 times greater than the above. Under these conditions only the coarsest dirt would be taken out and everything smaller would go through were it not for the fact that a small proportion of alum added to most waters produces a precipitation or coagulation, which collects the suspended matter and thus helps in its retention by the sand. The mechanical filters all require alum. They lack the test of long experience and wide use which the slow sand filtration systems have had. Their attractive features are a moderate degree of cheapness and considerable degree of compactness.

Mr. Franklin J. Firth, of Philadelphia, the Chairman of the Citizens' Filtration Committee, in the Annals of Hygiene, June, 1896, under the caption, "Purification of City Water Supplies by Sand Filtration," says:

"*Complete Mechanical Systems* on the best American model cost, exclusive of land, about $20,000 for a capacity capable of filtering 2,000,000 gallons per day."

"*Complete Artificial Systems* on the best European model cost, exclusive of land, about $70,000 per acre, and filter 2,000,000 gallons per acre in each 24 hours."

Mr. Firth's estimate on the latter is for covered filters. For uncovered filters on the European system, the costs have been estimated at only $42,000 to $48,000 per acre. We can do still better than that, for at Lawrence we have embodied all the essential features of the "now somewhat ancient or old English method" and have perhaps made a few improvements, and yet the Lawrence filter only cost $26,000 an acre. This

brings us down so close to the $20,000 figure of Mr. Firth for the mechanical system that we may fairly say that but for the cost of land one may be as cheaply installed as the other, and inasmuch as we are not compelled to build filters on expensive land this objection also falls to the ground and leaves the unpatented Lawrence system with its long and honorable pedigree face to face with the as yet comparatively unknown patented mechanical systems. If it were not a matter of life or death to so many persons we would say, see if we can't save the city a little money by putting in a cheaper system which may be all right. It seems to me, however, that the proper attitude is that of conservatism. There are a certain number of lives to be saved (some 200 to 300 a year in Pittsburg), and there is a well-known way of saving them. Why seek another? If we could look into the future and see those who are yet to be sacrificed before filtration can possibly be accomplished we would not allow a single moment's delay.

4. *The Craig Street Experiment in Sand Filtration.*—In the early part of the summer of 1895, the facts concerning our bad water supply having been forcibly brought home to us, a little body of young men under the name of the Citizens' League, undertook to do some educational work. As an object lesson in the art of getting purer water they decided to build a filter and operate it for a considerable period, at a place where all could see it.

Appeals for subscriptions were sent out in July, and gratifying responses were received, so that we were able to begin work at once.

Plans were made for a filter tank of about 1,500 gallons capacity and designed to filter about 2,000 gallons per day. The construction of this tank was kindly done for us by the Central Expanded Metal Co., and on account of its extreme simplicity and ingenuity it is now described.

A concrete foundation, 8 feet in diameter and 18 inches deep was first laid. In this was embedded the necessary pipe

for the filtered water outlet, and also the ends of the upright 7-16 inch studding rods which formed the frame on which the expanded metal lathing was subsequently wired. The studding rods were set six inches into the concrete, were placed $15\frac{1}{2}$ in. apart and were shouldered into a $\frac{3}{4}''$x$\frac{3}{8}''$ template at the top. Metal lathing sheets 20″ wide by 8′ long of expanded metal having meshes 7-16″x$\frac{3}{4}''$ and so shaped as to form small ledges to retain the mortar, were wired with soft No. 16 steel wire to the studding rods. The bottom of the tank was made of heavier expanded metal, such as is used for fencing, with meshes 7″x$3\frac{3}{4}''$. The pieces were laid on the concrete with joints breaking. (The framework and the finished tank are well shown in the Eng. News, Dec. 12th, 1895.) On this framework was plastered cement mortar composed of one part American Portland (Alpha) cement and two parts river sand. The cement was applied in coats inside and out until a total thickness of 2″ was obtained. No special care was taken to shield the work from the sun, and but little dampening was done. After about ten days the tank was coated inside with ashphalt paint and the filtering material put in place. We were furnished with Allegheny river sand having a uniformity coefficient of 2.6 and an effective size of 0.30 mm. After washing with a hose in an inclined mortar box the sand was very much cleaner but was unfortunately much less fine. Its analysis then showed a uniformity coefficient of 2.2 and an effective size of 0.34 mm. This was undesirably coarse, but we decided to push on with it at a sacrifice of some degree of efficiency rather than to delay our object lesson. On the bottom of the tank, which sloped to the outlet, we placed a 2″ layer of $\frac{1}{2}''$ gravel graded level. On this was placed 2″ of $\frac{1}{4}''$ gravel, then $1\frac{3}{4}''$ of $\frac{1}{8}''$ gravel and $1\frac{1}{4}''$ of coarse sand. Above these layers came 4′ 6″ of washed sand.

It was desirable to introduce the raw water quietly into the filter so that the top layer of sand need not be agitated. To effect this an inflow bay about one foot wide projected from

the top of the tank. Into this the raw water flowed, passing thence through a one-inch hole in the side of the tank. The bay also contained a vertical overflow pipe to regulate the height of the water in the tank. In practice we found that the water stood at about 6 inches below the top of the tank, making a depth of 20 inches of water on the sand. Six gauge tubes at distances of 13 inches apart served to show the "loss of head" as filtration proceeded. The filtered water flowed out through a goose-neck iron pipe into the inflow bay, and thence either to the street for public use or to the sewer at times just after scraping. After running the filter for a month exposed to the action of the atmosphere and small boys, we housed it, providing thereby a laboratory for chemical and bacteriological tests of the filtered and unfiltered water.

Our work with the filter during the year 1895-96 naturally divides itself into nine periods or runs, the intervals between successive scrapings. The *first tables* give the amounts of water filtered during these runs, the number of tests made and the average bacterial results. The *following tables* show the bacterial results in Run No. 1 and similar data for the other eight runs. Considering that the sand used was neither so fine nor so uniform as should have been selected, and that it was necessary to refill from below with *raw* instead of *filtered* water after each scraping, it is believed to be a very creditable showing to have removed over 90% of all the bacteria applied to the filter. With the continuous, careful manipulation and supervision which sand filters operated on a large scale in Pittsburg would receive, there is no question that their efficiency would be equal to that of those representing the best practice in other cities.

RUN NO. 1.

Filtration began Sept. 22d, 1895. The tank was filled from below with somewhat muddy raw water. On the first day the flow was not measured but is estimated not to have exceeded 500,000 gallons per acre. In three days the flow was

gradually brought up to 2,000,000 gallons per acre, and this rate was continued for 34 days, when it was made 2,500,000 gallons, which was thereafter the *normal rate of filtration*. The progress in bacterial removal is clearly shown in the table. Beginning at 27.6% removal on Sept. 25th, reaching 70% on Oct. 4th, the 13th day of the run, and finally reaching an apparent efficiency of 99% on the 37th day. For all bacterial work up to Dec. 17th I used hydrochloric acid—glycerine—meat extract-peptone—agar, which had been found suitable for some of the filter control work at Lawrence, Mass.; it will be seen by reference to the table following the detailed result of Run No. 2, that this acid agar yielded low results which were especially apparent in the case of the filtered water samples. It will also be seen in the comment on that table that this is the strongest indication we have that only common water bacteria passed in a living condition through the sand filter.

A few other features of Run No. 1 need explanation. The high result in sample of the September 26th water was due to irregular running. A local street repair necessitated shutting off the water at the filter for a few hours. After this our foreman turned it on at about four times the proper rate. This was changed to the 2,000,000 gallon rate that evening but the cultures made show the effect of this accident.

The following memoranda were made at the time and must be studied in conection with the tables of analyses :

EXPLANATORY NOTES CONCERNING RUN NO. 1.

(In the following memoranda words "city water" and "raw water" mean the same.)

1895.

September 19.—Gravel washed and put in place.

September 20.—Sand put in. Water exceedingly muddy.

September 22.—Water still muddy. Filled filter from below in 3½ hours. Let stand two hours. Started at 2:45 P. M. at about 500,000 gallons per acre per day.

September 23.—Slow filtration continued. Bacteriological tests made with (a) 2 % Taylor's neutral agar and (b) Fr's agar.

September 24.—Made cultures with Taylor's 2 % agar. Made rate of filtration 1,920,000. Filtered water clear.

September 25.—Rate had fallen to ½ speed during the night. Re-adjusted to 1,920,000. Made cultures using Taylor's and my own agar in duplicate.

September 26.—Raw water still quite muddy. Filtered water faintly opalescent since yesterday. Used only 1.5 % Fuller agar for to-day's cultures.

September 27.—At 7:30 A. M., Rogers shut off the inflow and outflow of water at the filter. Later in the day he turned on at about four times the proper rate. This was remedied at 7:30 P. M., and as filtered water was opalescent, I reduced speed to half regular rate.

September 28.—Room temperature in A. M., 61°F. A cold snap. Slow filtration continued until Saturday P. M.

September 29.—Water less muddy, but has a brown color due to vegetable matter. Filtered water still opalescent but not colored.

September 30.—Rate O. K. at 8 A. M. Supply diminished during the day so that level fell 3 inches Restored at 8 P. M. Temperature of culture room 50 to 60°F, September 30 to October 1

October 1.—Filtered water still slightly opalescent.

October 2.—Room temperature 56 to 60°F. Raw water only faintly opalescent.

October 3.—Culture temperature kept at 66 to 74°F from October 2. Raw water, brownish. Roof will be over filter by to-morrow.

October 4.—Raw water, brown. Filtered water, colorless. Cultures made.

October 5.—Temperature 62 to 74°F. Rate, O. K. Filtered water slightly opalescent.

October 6—Many visitors. Neighbors coming for water.

October 7—Raw water still brown, but nearly clear.

October 8—Inflow partly clogged. Head fell about 6 inches. Restored.

October 9—Raw water, brown.

October 10—Filter running O. K. in A. M. Shut off by plumber during the day and remained so all night. Heavy frost this A. M. Loss of head in 18 days, $\frac{3}{4}$ inch.

October 11—Blank culture showed no colonies. On October 8, there had been 85 % of bacteria removed. Raining in the evening. Filtration stopped from morning of October 10 to 8 P. M. October 11. Started up at 1,920,000 rate.

October 12.—Weather cool and rainy. City water fairly clear. Rate, $\frac{1}{20}$ lower. Loss of head now 1 inch.

October 13.—Loss of head continues steadily since the rest from October 10th to 11th took place. Filtered water, bright.

October 14.—Raw water, nearly clear. Filtered water perfectly so. Weather moderated.

October 15.—Filter shut off at inlet and outlet from 8 A. M., 10-15, to 8 A. M., 10-16, to make rain-water connection to the sewer. Loss of head about $\frac{1}{2}$ inch per day now. Tested tank for leakage in 24 hours. Found none.

October 16.—Started again at 1,920,000 rate. Raw water slightly cloudy. Filtered water, clear.

October 17. Loss of head continues. Total, 3 inches now. No sub-surface clogging. Raw water, cloudy. Filtered water, bright.

October 18. Loss of head during the day, $\frac{3}{4}$ inch. Filtered water, bright. Frost last night. Warm to-day.

October 19.—Water, clear. Rate, O. K. Absent 10-19 to 10-23.

October 23.—City water still quite clear.

October 24.—City water only faintly opalescent. (Sixteen new cases of typhoid in Allegheny and four in Pittsburg to-day.) Stoppers of agar—agar tubes which I began to use yesterday were wet on account of standing in water in closed vessel after sterilizing. It is probable that there has been some dilution of the contents by dripping from the cover. Loss of head continues at 1 inch per day.

October 25.—City water, opalescent. Filtered water, clear as crystal; it has been so for some time now.

October 26.—Made up new batch of 1.5%. "Fuller" acid agar.

October 27.—Rate changed at 1 P. M. from 1,920,000 to 2,400,000 gallons per acre per day.

October 28.—Loss of head, 11¾ inches. Temperature of filtered water, 53° F. Sterilized collection bottles used to-day for the first time.

October 29.—City water nearly clear. Filtered water, bright. Closed gauge "B" to keep out air. Temperature of filtered water, 53° F. At 8 P. M., loss of head, 14½ inches. New 10-26, agar used to-day.

October 30.—No rain. Cold and frosty. City water slightly opalescent. Loss of head, 15 inches. Rate, 2,400,000.

October 31.—Rain to-day. City water only slightly opalescent. Filtered water, bright. Loss of head, 16 inches. Rate, 2,400,000.

November 1.—Raw water, opalescent. Filtered water, bright. Loss of head, 17½ inches. Rate slightly under 2,400,000.

November 2.—Filtered water exhibited at Sanitation Commission meeting and cultures of 10-28, 10-29, showing 99% efficiency.

November 3.—Loss of head, 19½ inches. Filtered water, clear.

November 4.—City water distinctly opalescent but no rains lately. Filtered water, bright. Rate, 2,300,000 at 8 A. M. Changed to 2,500,000. Loss of head at 6 P. M., 21 inches.

November 5.—Loss of head, $22\frac{3}{4}$ inches. Water appearances as yesterday. Cultures made with both gelatine and agar

November 9.—Loss of head, $31\frac{1}{2}$ inches. Rate, 2,300,000. Restored.

November 10.—Loss of head, $32\frac{1}{2}$ inches. Rate, 2,400,000. Tank measurements checked over and found to be as follows:

Width of tank at top over all, 7 ft., $2\frac{3}{4}$ in.
Thickness of wall at top moulding, 3 in.
Inside diameter of tank, 6 ft., $8\frac{3}{4}$ in.
Walls of tank below moulding, $2\frac{3}{8}$ in. thick.
Distance from top of moulding to surface of water, 6 in.
Depth of water on sand, 12 in.
Depth of tank, 78 in.
From these data, we calculated:
Area of filter surface, 35.56 sq. ft. =.000816 acre. For a rate of 2,500,000 gallons per acre per day as we have 22.13 gallons per inch depth of tank, we would have 3.84 inches fall per hour, and a delivery of 84.96 gallons per hour or 89.33 cc. per second. We used a bottle holding 2475. cc. for regulating rate. At 2,500,000 gallons rate, it filled in 27.7 seconds.

November 11—Raw water becoming muddy. Shut off supply at 11 P. M. Loss of head about 36 inches and could not get 2,500,000 rate.

NOTES ON RUN NO. 2.

November 12, 1895.—First scraping. Found brown scum like ordinary river silt with clean sand $\frac{1}{2}$ inch below. Removed 8 bucketfuls of sand for an average depth of about $\frac{1}{2}$ inch. Impossible to scrape evenly; used flat metal scoop, made of a square tin box opened by cutting out one end; sand had not settled perfectly level.

Depth from top of tank to top of sand, (north side) $20\frac{1}{4}$ inches.
" " " " " " (south side) 25 "

I was surpised to find the former measurement because it had only shown 18 inches when the sand was full of water. There was a depression on the south side and an elevation in the center of the sand. Started refilling at 10 P. M., from below at rate of about 4 inches per hour. Water rather muddy; filtered water should have been used but had no supply.

November 13.—Water had risen to nearly fill the tank. Started at $\frac{3}{4}$ speed at 8 A. M.; at 8 P. M., it was delivering apparently clear water and I made cultures. Rate changed to about 2,500,000. Gauge readings showed no loss of head.

November 14.—Raw water more muddy. Filtered water bright. People have been asking for it.

December 2.—Rate 2,500,000. Loss of head $1\frac{3}{4}$–$1\frac{7}{8}$ inches. Raw water very muddy. Filtered water opalescent.

December 4.—Rate O. K. Loss of head $2\frac{3}{8}$ inches, P. M.

December 5.—Rate O. K. Loss of head $2\frac{1}{4}$ inches, P. M., but was only $1\frac{7}{8}$ inch in the morning. This curious phenomena has occurred several times. The loss of head would be greater at evening than on the following morning. Raw water muddy.

December 6.—Rate not given. Loss of head $2\frac{3}{8}$ in. at 8 A. M.

December 7.— " " " " $3\frac{1}{4}$ " 6 P. M.

December 9.—Rate 2,500,000. Raw water less muddy. Filtered water opalescent. Loss of head $3\frac{7}{8}$ inches at 8 A. M., and $4\frac{1}{16}$ inches at 8 P. M.

December 10.—Loss of head $4\frac{1}{8}$ inches at 8 A. M., and $4\frac{1}{4}$ at 6 P. M. Rate O. K. Filtered water clearer but still slightly opalescent.

December 11, 8 A. M.—Loss of head $4\frac{3}{8}$ inches. Rate O. K. Raw water nearly clear. Filtered water almost free from opalescence.

December 12, 8 A. M.—Raw water nearly clear. Filtered water almost bright, but brownish. Rate O. K. (2,-500,000.) Loss of head $4\frac{3}{8}$ inches; (slight leak in gauge.) Raw water has an oily smell.

December 13, 8 A. M.—Room 69° F.; cold outside. City water nearly clear and but slightly colored Filtered water colorless and nearly clear. Rate 2,400,000. Loss of head $4\frac{3}{8}$ inches; (gauge imperfectly repaired.)

December 14, 8 A. M.—Raw water nearly clear. Filtered water clear at last. Loss of head $4\frac{1}{2}$ inches. Gauges wired.

December 15, 10 A. M—Rate O. K. City water still nearly clear. Loss of head at 1 P. M., $4\frac{5}{8}$ inches. (Gauges tight at last.)

December 16.—City water nearly clear. Filtered water bright. Loss of head at 8 A. M., $4\frac{5}{8}$ inches. Rate slightly under 2,500,000; restored. Weather warmer. Loss of head at 6 P. M., $4\frac{3}{4}$ inches.

December 17, 8 A. M.—Water appearances same. Rate O. K. Loss of head $4\frac{3}{4}$ inches.

December 18, 8:30 A. M.—Loss of head 5 inches, (slight leak.) Filtered water sparkling. Made first cultures with 2% neutral agar-agar. Rate interfered with during day by some one; found door unlocked. Rate had fallen to 2,100,000; restored.

December 19, A. M.—Loss of head $5\frac{1}{8}$ inch. Gauge or speed indicator used Cultures of 12–17 made on same day the tubes were filled.

December 20, 8 A. M.—Raw water nearly clear. Filtered water sparkling. Rate slightly low; made it 2,500,000. Loss of head $4\frac{7}{8}$ inches. Temp. raw water $41\frac{1}{2}$°. Filtered water 44°. 8 P. M. Loss of head $4\frac{7}{8}$ inches. Water temps. same.

December 21, 8 A. M.—Loss of head 5 inches. Rate slightly fast; restored.

December 23, A. M.—Raw water very muddy; muddiest yet. Filtered water very clear. Rate O. K. Loss of head $5\frac{3}{8}$ inches. Water temps. 43° F. for raw, and 44° for filtered water.

December 24, A. M.—Water temps. $43\frac{1}{2}$° F. for raw, and 45° for filtered water. Raw water very muddy. Filtered water slightly cloudy. Loss of head $6\frac{1}{16}$ inches.

December 25, 7:30 P. M.—Raw water slightly less muddy. Filtered water bright, except in large volume. Rate O. K. Loss of head $7\frac{1}{8}$ inches.

December 26, 6 P. M.—Very heavy rain this P. M. Raw water still bad, though less muddy. Filtered water bright in small volume. Loss of head $7\frac{5}{16}$. Rate O. K. by indicator.

December 28.—8 A. M. Rate, 2,500,000, although speed indicated had risen 1 inch in two days. Loss of head, $3\frac{1}{4}$ inches. Temperature of both raw and filtered water, $45\frac{1}{2}$° F. Raw water still very muddy. Filtered water quite opalescent.

December 29.—10.30 A. M. Rate slightly high. Loss of head, $3\frac{3}{8}$ inches.

December 30.—8 A. M. Loss of head, $3\frac{5}{8}$ inches. Raw water very cloudy. Filtered water, cloudy.

December 31.—7.45 A. M. Loss of head $4\frac{5}{8}$ inches. Filtered water nearly clear. Raw water still less cloudy. At 1.45 P. M. rate still slow.

1896.

January 2, 8.30 A. M.—Loss of head, $6\frac{1}{16}$ inches. Filtered water nearly clear. Raw water, cloudy. Rate, indication slightly low; restored.

January 3, 7.45 A. M.—Raw water quite muddy. Filtered water almost clear, faintly opalescent. Rate, 2,500,000. Loss of head, 7 inches.

January 5, 7 P. M.—Have had zero weather since January 3d. Gauges frozen. Rate O. K. Raw water, cloudy and brownish. Filtered water, clear.

January 6, 8.15 A. M.—Gauges all frozen. Raw water still cloudy. Filtered water, clear. Rate, low, not changed. Water in filter fell below gauge B.

January 7, 8 A. M.— Rate, 2,300,000. Changed to 2,500,000. Raw water nearly free from mud. Filtered water slightly opalescent. Loss of head, $10\frac{7}{8}$ inches.

January 8, 8 A. M.—Rate, 2,450,000; restored. Raw water nearly free from brown color. Filtered water nearly bright. Loss of head, $11\frac{3}{4}$ inches.

January 9, 8 A. M.—Rate O. K Loss of head, $12\frac{1}{2}$ inches. Filtered water, bright. Raw water slightly opalescent.

January 10, 8.30 A. M.—Rate slightly low; restored. Raw water nearly clear. Filtered water, bright. Loss of head, $12\frac{5}{8}$.

January 11, 7.45 A. M.—Raw water, $39\frac{1}{2}$ inches. Filtered water, $39\frac{3}{4}$ inches. Loss of head, $11\frac{1}{2}$ inches. Raw water nearly clear. Filtered water, bright.

January 13.—Rate slightly low; restored. Raw water, clear. Filtered water, bright and sparkling. Loss of head, $15\frac{3}{16}$.

January 14, 1 P. M.—Snowing. Rate O. K. Loss of head, $16\frac{5}{16}$. Raw water, clear. Filtered water, sparkling.

January 15, 8.10 A. M.—Rate slightly low by gauge; restored. Appearances same as yesterday. Loss of head, $16\frac{3}{8}$.

January 16, 8 A. M.—Rate O. K. Raw water nearly clear in bulk. Filtered water, sparkling. Loss of head, $17\frac{3}{8}$.

January 17, 8 A. M.—Rate slightly low. Restored. Raw water, clear. Filtered water, sparkling. Loss of head, $18\frac{1}{8}$. Temperatures, raw, $39\frac{1}{2}$° F. Filtered, 40° F.

January 18, 8.15 A. M.—Rate low. Restored. Appearances same. Loss of head, $19\frac{5}{8}$ inches.

January 19, 1 P. M.—Rate restored. Opened gauge B and let out the air which had accumulated in considerable amount.

January 20, 8 A. M.—Still a little air coming from B. Closed at 8 A. M. Raw water, clear. Loss of head, 18 inches. Rate slightly over 2,500,000.

January 21, 8 A. M.—Appearances same as since January 17. Loss of head, 20$\frac{3}{8}$ inches. Opened gauge B and let out more air. Gauge C showed loss of head, 20$\frac{3}{8}$ inches, after closing up gauge B. Opened again and C fell to 20$\frac{1}{8}$ inches and then settled to 20$\frac{1}{8}$ in 5 minutes. In 15 minutes more it settled to 20$\frac{3}{8}$ inches.

January 22, 8 A. M.—Rate low. Restored. Raw water, clear. Filtered water, sparkling and bright. Loss of head, 21$\frac{3}{4}$ inches. Water temperature, 39° for both.

January 23, 8 A. M.—Rain. Rate low. Restored. Closed gauge C at 28$\frac{3}{8}$ inches. Appearances as yesterday.

January 24.—Heavy rain. Rate low. Restored. Loss of head, 27$\frac{3}{8}$ inches. Appearances: raw water, opalescent: filtered water, bright and clear.

January 25, 9 A. M.—Rain. Rate low. Restored. Loss of head, 28$\frac{3}{8}$ inches. Raw water, cloudy. Filtered water, sparkling.

January 26.—Raw water, very muddy.

January 27, 7:30 A. M.—Rate low. Turned off water. Loss of head, 31$\frac{3}{8}$ inches. Raw water, very muddy. Filtered water, bright.

NOTES ON RUN NO. 3.

1896.

January 27, 6 P. M.—Temperature room, 113°F. At 7:30 P. M. water was in general over 2 feet below the sand. Several pools were siphoned off and the surface scraped deeply $\frac{3}{4}$ inch to 1 inch. The scum was brown and seemed to extend *in* only about $\frac{1}{4}$ inch. Nine bucketfuls of sand removed. Re-filled, beginning at 9 P. M., at the rate 15 inches per hour. This would have made it full at 1 A. M., after which it overflowed in the reverse direction until next morning.

January 28, 8 A. M.—Started at full rate (2,500,000). Cultures made at 5 P. M.

January 29, 8 A. M.—Rate, $\frac{27}{29} \times 2,500,000$. Changed to normal before taking sample for culture. Water temperatures both $38\frac{1}{2}$°F. Loss of head, $10\frac{5}{8}$ inches. Filtered water slightly opalescent. Raw water slightly less muddy.

January 30.—Rate low by gauge. Restored before taking sample. Filtered water faintly opalescent. Loss of head calculated from B, $5\frac{5}{8}$ inches.

January 31, 8:15 A. M.—Rate low. Restored. Raw water, less muddy. Filtered water quite clear. Loss of head, $5\frac{7}{16}$ inches. (Calculation from B.)

February 1, 8:15 A. M.—Rate high. Restored. Loss of head, $5\frac{7}{16}$ inches. Calculation from B. Raw water much less muddy. Filtered water opalescent. Started filtered water running to the street at 8:30 A. M.

February 2, 10 A. M.—Rate high. Restored. Loss of head, $5\frac{1}{8}$ inches, calculation.

February 3, A. M.—Rate slightly low. Restored. Raw water, growing muddy. Filtered water, nearly clear. Loss of head $6\frac{3}{8}$ inches, calculation. Filter has been uncovered since cleaning.

February 4, 8 A. M.—Rain. Rate $\frac{277}{285}$ low; restored. Raw water, very muddy. Filtered water, faintly opalescent Loss of head, $5\frac{7}{8}$ inches, calculation.

February 5, 8 A. M.—Damp; slightly cooler. Rate, slightly low; restored. Raw water still muddy. Filtered water nearly clear. Loss of head, $6\frac{3}{8}$ inches, calculation.

February 6, 7:45 A. M.—Loss of head $6\frac{1}{8}$ inches, calculation; rainy. Raw water very cloudy. Filtered water nearly clear.

February 7, 8:15 A. M.—Rate too high; reduced. Raw water muddy. Filtered water almost clear. Loss of head $3\frac{7}{8}$ inches, calculation.

February 8, 8:30 A. M.—Rate high; restored. Loss of head $3\frac{3}{4}$ inches, calculation. Raw water slightly less muddy. Filtered water clear.

February 9.—Snow.

February 10, 8 A. M.—Raw water muddy. Filtered water clear. Rate O. K. Loss of head $3\frac{3}{8}$ inches, calculation from B. Used gelatine of December 17, '95.

February 11, 8 A. M.—Rate slightly low; restored. Loss of head $3\frac{5}{8}$ inches, calculation from B. Raw water less muddy. Filtered water nearly clear.

February 12, 8 A. M.—Rate 2,500,000. Gauge C at last $11\frac{1}{2}$ inches. Evidently calculations based on B have been wrong because B has been almost level with top of sand during this run. Raw water still muddy. Filtered water faintly opalescent.

February 13.—Rate O. K. Rain. Loss of head 12 inches. Raw water less muddy.

February 14.—Colder and snow. Rate slightly low; restored. Raw water much less muddy. Filtered water nearly clear. Loss of head $12\frac{3}{4}$ inches.

February 15, 8:15 A. M.—Rate O. K. Loss of head $13\frac{1}{4}$ inches. Filtered water clear.

February 17.—Rate gauge frozen up. Filtered water clear. Raw water muddy. All gauges frozen.

February 18, 8 A. M.—Rate O. K. Loss of head $14\frac{15}{16}$ inches. Appearance the same.

February 19, 8 A. M.—Rate slightly low; restored. Loss of head $16\frac{3}{8}$ inches. Appearance the same.

February 20, 11:15 A. M.—Snow. All gauges frozen. Raw water less muddy. Filtered water almost clear.

February 21, 8:15.—Fire out; cultures frozen; gauges frozen. Made new cultures at 1 P. M.

February 24.—Fire out since Friday night and still so. Rate very low; restored. Loss of head $23\frac{3}{4}$ inches. Raw water clearer. Filtered water bright.

February 25, 8 A. M.—Rate low; restored. Loss of head $25\frac{1}{8}$ inches. Raw water improving. Filtered water bright.

February 26, 8 A. M.—Rate slightly low; restored. Gauge not readable. D=$28\frac{3}{8}$ inches. Appearance the same.

February 27, 8 A.M. Rate low and not restorable. D=$29\frac{3}{8}$ inches loss of head. Raw water nearly clear. Filtered water sparkling.

February 28, 8:15 A. M.—Rate low. D=$30\frac{7}{8}$ inches loss of head. Raw water nearly clear. Filtered water bright. Turned off water.

RUN NO. 4.

February 28.—Scraped sand at 8 P. M., and re-filled so that there was about 5 hours of reverse flow after filling. The water used for re-filling was nearly clear. The depth of scraping was not recorded.

February 29.—Started at 8 A. M., at about 2,000,000 gallons rate.

March 1, 12 M.—Loss of head, 8 inches. Rate made, $\frac{28}{36}$ normal. Raw water nearly clear. Filtered water, sparkling.

March 2, 8 A. M.—Colder and snow. Loss of head; $9\frac{7}{8}$ inches. Appearances the same.

March 3, 9 A. M.—Rate slightly low; restored. Loss of head, $10\frac{1}{8}$. Appearances same.

March 4, 8.15 A. M.—Rate O. K. Loss of head, $8\frac{15}{16}$ inches. Appearances same.

March 5, 8 A. M.—Rate O. K. Loss of head, $8\frac{5}{8}$ inches. Raw water not so clear. Filtered water, sparkling.

March 6.—Rain and much warmer. Rate low; restored. Loss of head, $13\frac{3}{8}$. Raw water slightly opalescent. Filtered water, sparkling.

March 7.—Rainy and still cooler. Rate low; restored. Loss of head, $17\frac{13}{16}$ inches. Raw water, etc., appeared as yesterday.

March 9, 8 A. M.—Rate higher; restored. Loss of head, $11\frac{1}{8}$ inches. Raw water, opalescent. Filtered water, sparkling. 7 P. M. Rate changed to normal, 2,500,000.

March 10.—Snow. Rate slightly low; restored. Loss of head, 13 inches. Appearances as yesterday.

March 11, 8.30 A. M.—Colder and snow. Rate low; restored. Loss of head, $15\frac{7}{8}$ inches. Appearances same. 2.15 P. M. Bacillus prodigiosus culture added, 100 cc. Culture made which showed 2,444 in 0.5 cc. diluted culture.

March 12, 8 A. M —Rate O. K. Loss of head, $16\frac{1}{4}$ inches. Raw water, cloudy. Filtered water, clear. 1.45 P. M. Bacillus prodigiosus added again and controlled by a culture which showed 2,956 in .5 cc. diluted culture.

March 13, 9.10 A. M.—All gauges frozen. Raw water much clearer. Filtered water, clear.

March 14, 8.15 A. M.—Rate high; restored. Loss of head, $9\frac{3}{8}$ inches. Raw water still opalescent. Filtered water, bright.

March 15, 3.15 P. M.—Gauges thawed. Loss of head, 8 inches. All levels rose. (Why?) Clogging diminished by freezing.

March 16, 8.30 A. M.—Snow. Rate O. K. Loss of head, $9\frac{1}{8}$ inches.

March 17, 8 A. M.—Rate O K. Loss of head, $9\frac{3}{8}$ inches. Raw water nearly clear. Filtered water, sparkling.

March 18, 8.15 A. M.—Milder. Rate O. K Loss of head, 10 inches. Appearances same.

March 20, 8.45 A. M.—Cold and snow. Rate slightly low: restored. Loss of head, $11\frac{7}{8}$ inches. Raw water, opalescent. Filtered water, clear and bright.

March 21, 7.45 P. M.—Clear and cold. Rate nearly O. K. Loss of head, $12\frac{5}{8}$ inches. Appearances same.

March 22, 12 45 P. M.—400 cc. bacillus prodigiosus culture added. Made culture at 12.45 P. M., of $\frac{1}{100}$ of .5 cc.

of peptone glucose, 5 day culture of February culture received from Lawrence. This was due at outlet at 7.30 A. M., March 23.

March 23, 7.40 A. M.—Cultures made. Rate, ½ inch low: restored. Loss of head, 16¼ inches. Raw water very muddy on account of rise. Filtered water very bright and clear.

March 24, 7:30 A. M.—Loss of head, 18 inches. Rate ¼ inch low: restored. Raw water very muddy. Filtered water, bright.

March 25, 7 P. M.—Raw water muddy. Filtered water clear. Rate ¾ inch low: restored. Loss of head, 21½ inches.

March 26, Rainy: colder. Loss of head, 23¾ inches. Rate ½ inch low; restored. Raw water very muddy. Filtered water very bright.

March 27, 6 P. M.—Raw water still muddy: longest muddy period. Rate ½ inch low: restored. Loss of head, 26 inches.

March 28, 6:15 P. M.—Rate ½ inch low: restored. Loss of head, 27¼ inches, calc. from D. Raw water very muddy. Filtered water clear.

March 29, 12:30 P. M.—Rate ½ inch low, wide open. Loss of head, 29⅞ inches.

March 30, 7:53 A. M.—Loss of head, 30⅞ inches. Rate ½ inch low. Raw water very muddy. Filtered water nearly bright. Shut off water preparatory to cleaning. It took 10 hours to run down to about 48 inches on gauge.

RUN NO. 5.

March 30.—Scraped, at 6 P. M., ½ to ¾ inch. Time in scraping, 40 minutes. Appearance before scraping, light brown and not at all slimy. No pools: evidently been working evenly: scraper marks from last cleaning all plain. Time in re-filling at 12 inches per hour equal 4 hours: started at 10 P. M. at rate 1,800,000: water

used for filling was very muddy; rivers rising fast. Loss of head at start, about 3 inches; no reverse flow this time.

March 31, 7:40 A. M.—Loss of head, 3 inches. Raw water very muddy. Filtered water slightly opalescent. At 7:15 P.M. man came for and insisted on having water. Rate 1,900,000.

April 1, 7:50 A. M.—Rate changed to 2,250,000. Raw water very muddy. Filtered water opalescent. 1 B. P. in yesterday's culture of filtered water. Loss of head, $4\frac{3}{4}$ inches.

April 2, 7:45 A. M.—Rate changed to 2,300,000. Filtered water opalescent. At 7:30 P. M. culture made. Rate 31. Loss of head, $5\frac{5}{8}$ inches. Raw water muddy. Filtered water opalescent.

April 3, 7:45 A. M.—Rate changed to 2,500,000. Raw water less muddy. Filtered water markedly opalescent. 5:15 P. M. Loss of head, $6\frac{3}{4}$ inches.

April 4, 7:45 A. M.—Rate $\frac{1}{16}$ inch low; restored. Raw water improving. Filtered water opalescent.

April 5, 12 Noon.—Rate O. K. Loss of head, $7\frac{5}{8}$ inches.

April 6, 7:30 A. M. Rate $\frac{1}{8}$ inch low; restored. 7:30 P. M. Raw water cloudy. Filtered water nearly bright. Loss of head, $8\frac{1}{8}$ inches Rate O. K.

April 7, 5:45 P. M.—Rate low; restored. Loss of head, $8\frac{5}{8}$ inches. Raw water slightly cloudy. Filtered water clear.

April 9, 8:45 P. M.—Loss of head, 10 inches. Rate $\frac{1}{16}$ inch low; restored. Raw water slightly cloudy. Filtered water bright.

April 10, 6 P. M.—Rate $\frac{1}{16}$ low; restored. Raw water slightly muddy. Filtered water bright. Loss of head, $10\frac{1}{4}$ inches.

April 11, 10:45 A. M.—Rain. Rate O. K. Loss of head, $10\frac{13}{16}$ inches.

April 13, 7:45 A. M.—Heavy rains of Friday and Saturday show in raw water to-day. Rate slightly low: restored. Loss of head, $11\frac{5}{8}$ inches. Raw water muddy.

April 14, 9 P. M.—Warm and clear. Loss of head, $12\frac{1}{2}$ ins. Raw water still muddy.

April 15, 7:45 A. M.—Rate slightly low: restored. Loss of head, $12\frac{7}{8}$ inches. Raw water still muddy.

April 16, 7:45 A. M.—Clear and warm. Rate O. K. Loss of head, $13\frac{3}{8}$ inches. Raw water still muddy.

April 17, 9 A. M.—Clear and warm. Rate O. K. Loss of head, $13\frac{5}{8}$ inches. Raw water less muddy.

April 18, 8 A. M.—Fair and warm. Rate O. K. Loss of head, $13\frac{13}{16}$ inches. Raw water less muddy.

April 20, 8 A. M.—Rate O. K. Loss of head, $14\frac{1}{2}$ inches. Raw water nearly clear.

April 21, 8 A. M.—Rain last night. Rate O. K. Loss of head, 15 inches. Raw water nearly clear.

April 22, 7.45 A. M. Rate low; restored. Loss of head, $16\frac{5}{16}$ inches. Raw water nearly clear.

April 23, 11.45 A. M.—Rate low; restored. Loss of head, $18\frac{1}{4}$ inches. Raw water decidedly muddy.

April 25.—Rate, etc., regulated. Filtered water, bright.

April 27, 7.30 P. M.—Rate, $\frac{1}{2}$ inch low; regulated.

April 28.—Loss of head $23\frac{3}{8}$ inches. Raw water unusually clear. Filtered water, bright.

April 29, 10.45 P. M.—Rate O. K. Loss of head, $23\frac{5}{8}$ inches.

Absent till May 5.

May 5, 7.15 P. M.—Rate slightly above mark; restored. Loss of head, $26\frac{1}{4}$ inches. Raw water slightly cloudy. Filtered water, bright.

May 9, 10 P. M.—Rate apparently gone up 1 inch; restored. Loss of head, $24\frac{1}{4}$ inches. Filtered water, bright.

May 10, 12 M.—Rate false; indication 2,000,000, really 2,100,-000.

May 13, 8 P. M.—Heavy rain Monday night and all this afternoon. Rate 1,900,000. Loss of head, 26 inches. Raw water slightly cloudy. Filtered water, bright.

May 14, 10.45 P. M.—Loss of head, 26½ inches. Raw water slightly muddy. Filtered water, bright.

May 15, 9.35 P. M.—Loss of head, 26⅞ inches. Raw water slightly cloudy. Filtered water, bright.

May 16, 7.45 P. M.—Rate 1,900,000. Raw water slightly cloudy. Filtered water, sparkling. Loss of head, 27 inches.

May 18, 7.45 A. M.—Rate 1,800,000 and loss of head 27⅛ inches. Raw and filtered water both clear. Shut off the inflow.

RUN NO. 6.

May 18, 7.30 P. M.—Scraped ¼ inch to ½ inch, removing only about half as much sand as usual. Started refilling at 8.45 P. M. from below, with raw water which was quite clear.

May 19, 7.45 A. M.—Found tank and inlet both overflowing freely. Never had such clear raw water. Started at 2,200,000 rate.

May 20, 7.45 A. M.—Rate at usual head, 2,000,000. Loss of head, 8½ inches. Raw water so clear that sand is distinctly visible. 10 P. M.—Turned water to street.

May 21, 8 P. M.—Rate changed to normal, 2,500,000. Loss of head 12¾ inches. Raw water still bright and clear.

May 22, 9.15 P. M.—Rate low; changed to 2,500,000. Loss of head, 15½ inches. Temperature water, 68½%. Raw water, sparkling.

May 25, 10 P. M.—Rate O. K. Loss of head, 21⅛ inches. Raw water still bright.

May 26, 10 P. M.—Loss of head, 20⅜ inches calculated. Raw water still clear.

May 27, 8 P. M.—Rate slightly low; changed to normal. Loss of head, 22½ inches. Raw water still clear and can see sand plainly.

May 29, 6 P. M.—Rate O.K. Loss of head, 25½ inches. Raw water slightly cloudy. Filtered water, bright.

June 2, 8.30 P. M.—Rate fallen to 1,900,000; open full. Loss of head about 32¾ inches. Raw water nearly clear. Filtered water, bright.

June 4.—Found door fastened inside.

June 8.—Found that marauders had been in and done damage by stirring up the sand of the filter.

June 9.—Turned off water and let it run to sewer. Found gauges had risen to about 20 inches on account of disturbance.

RUN NO. 7.

June 9, 8 P. M.—Found sand all softened up as never before by walking. Scraped about 2 inches deep all round and started to re-fill at 6 inches per hour. Removed about 3 times as much sand as usual. Raw water very muddy. Nailed windows.

June 10, 8 A. M.—Turned on water. Rate 100 cc. in 2 seconds; or 1,400,000. 8.45 P. M.—Changed rate to 1,800,000; loss of head, 2¼ inches. Raw water muddier than for weeks.

June 11, 8 A. M.—Raw water horridly muddy. Filtered water, bright.

June 12, 7.45 A. M.—Changed rate to 2,200,000. Loss of head, 6½ inches. Appearances same. Turned water to street at 9 P. M. Filtered water a shade off bright. Raw water very, very muddy. Loss of head, 8½ inches.

June 14, 6.10 P. M.—Rate changed to 2,300,000. Raw water less muddy. Filtered water clear and bright.

June 16, 8 A. M.—Rate changed to 2,450,000. Loss of head, 15¾ inches. Raw water nearly clear.

June 18, 9 P. M.—Rate 2,450,000. Loss of head about 18¼ inches. Raw water quite clear. Filtered water, bright.

June 21, 12.30 P. M.—Rate changed from 2,200,000 to 2,450,000. Loss of head, 20⅞ inches. Raw water, muddy. Filtered water, clear.

June 23, 8 A. M.—Rate 2,400,000, approximately. Loss of head, 22 inches. Raw water, muddy. Filtered water, bright.

June 26, 6:30 P. M.—Rate 2,100,000. Loss of head, 25¼ inches. Raw water horribly muddy, "June rise" began yesterday; muddiness awful; worst yet.

June 28, 8:30 P. M.—Rate 2,300,000. Loss of head, 21½ inches. Raw water very muddy, but has been improving. Filtered water faintly opalescent; filtered water was bright yesterday.

June 30, 7:30 A. M.—Rate has risen to 2,450,000. Loss of head, 18½ inches. Raw water still very muddy. Filtered water opalescent and no one has been in to disturb it.

RUN NO. 8.

July 3.—Cleaned and started to refill. Mr. St. John regulated it next day to 2,000,000.

July 8.—Increased rate to 2,200,000.

July 16, 8 P. M.—Rate 2,000,000. Loss of head, 7 inches. Raw water vilely muddy. Filtered water nearly bright.

July 20, 8 P. M.—Rate 1,950,000. Loss of head, 8¾ inches. Raw water very muddy still. Filtered water nearly bright.

July 24, 8 P. M.—Rainy for several days past. Rate 1,900,000. Raw water muddy and has been so for over two weeks, but the filtered water is bright. Loss of head, 9⅝ inches.

August.—During the month kept going at low rate, about 2,000,000 up to August 16.

RUN NO. 9.

August 16.—Scraped by P. H. T., probably more lightly than before.

September 6.—Rate 1,900,000. Could not increase because of rusty pipe.

September 15—Rate 1,700,000. Loss of head, 23 inches. Raw water nearly clear and has been so for some time. Filtered water very clear.

September 16, 6 P. M.—Made cultures.

September 19.—Raw water is clear.

September 22, 6:30 P. M.—Rate 1,400,000. Loss of head, about 28 inches. Made cultures and then shut off.

EFFECT OF CHANGING FROM AN ACID TO A NEUTRAL CULTURE MEDIUM.

Up to December 17th, 1895, with a few exceptions, I had used an acid glycerine agar of the following formula:

Meat extract,	3 gm.	Made up with the usual precautions to 1 litre and filtered for use.
Peptone,	10 "	
Salt,	5 "	
Agar-agar,	15 "	
Glycerine,	6 "	
18 cc. normal H C l		

Between December 7th and 17th, the cultures had been lost because of the refusal to grow of nearly everything except moulds. In the table given below, we compare five days' results with the acid agar, with five days with the neutral 2% agar containing no glycerine nor HCl, but otherwise the same as the above.

	Average Bacteria per cc. Raw	Filt.
Dec. 3d to 7th inclusive	428.6	4.6
Dec. 17th to 21st inclusive	439.4	75.0

From this it is apparent that there are in the filtered water 94% more bacteria which will grow in a neutral than in an acid medium, whereas in the raw water the proportion which will grow in a neutral medium seems to be but very little larger. This shows that 94% of the bacteria in the filtered water at this time do not belong to the class to which the

bacillus of typhoid fever and the bacillus coli communi belong, viz., the class which grow readily in slightly acid media. This is a very important indication of the selective or rather of the restraining action of the filter. The bacteria of the typhoid or coli communis class are either retained at the surface of the sand and there die out or they die while passing slowly through the sand.

This fact is further proven by some parallel experiments in which neutral gelatine was used as a culture medium. The number of liquefying colonies were observed in both filtered and raw water cultures, and conclusions were drawn which point in the same direction as the acid medium test.

A BACILLUS PRODIGIOSUS TEST.

March 22d, 1896.

We prepared from a culture received from Lawrence, Mass., about 1 litre of glucose peptone solution, containing approximately 112,000,000 B. P., a scarlet bacillus which in its general characters, aside from color, bears much resemblance to that of typhoid fever.

This solution was fed in at the top of the filter at 12.45 P. M., on March 22d, 1896. At the then existing rate of flow, had they passed freely through the sand, these bacilli should have reported at the outlet 18 hours afterward. As a matter of fact none were found in the culture of the filtered water made then, nor were any B. P. found in the cultures of the next three days. The cultures of March 25 to March 29 were lost because of high temperatures.

The filter was scraped March 30th, and in the March 31st culture of the filtered water, 1 B. P. was observed. On April 2d, 1 B. P. On April 3d, 1 B. P.

This test seems to show that except at times immediately following scrapings, when in practice the water is usually wasted, bacilli resembling typhoid do not pass through a sand filter.

EXPERIMENTS WITH A TYPHOID CULTURE.

Craig Street, December, 1895.

Through the kindness of Mr. W. R. Copeland of the Lawrence Experiment Station, Lawrence, Mass., we received a culture tube marked "Harvard Laboratory from Berlin Culture, Dec. 9th." It was a stab culture in agar-agar.

It showed as a bluish white film extending down into the agar. It was kept in a cool room at 40 to 60°F. until Jan. 11th, 1896.

I then made one scratch and two stab cultures on 10% neutral gelatine and one scratch culture on 2% agar. These were kept at about 70° F. and growth observed. The agar showed a faint bluish growth in 24 hours. The gelatine stab cultures showed in 48 to 72 hours a bluish grey film extending downward. They had extended $\frac{1}{4}$ inch down in 96 hours.

These experiments confirm certain facts about the conditions under which the bacillus of typhoid fever will grow.

GELATINE CULTURES SHOWING DIFFERENT PROPORTIONS OF LIQUEFYING BACTERIA.

	RAW BACTERIA PER CC.			FILTERED BACTERIA PER CC.		
	Liquefying.	Total.	Per ct. Liquefying.	Liquefying.	Total.	Per ct. Liquefying.
January 30.	152	1278	12.0	25	175	15.0
" 31.	106	1160	9.0	33	175	18.0
February 1.	122	1106	11.0	29	103	28.0
" 3.	78	960	8.0	4	36	11.0
" 4.	52	1018	5.0	6	38	16.0
" 5.	140	1468	9.0	16	93	17.0
" 6.	121	1428	8.0	6	56	10.7
" 7.	75	1040	7.0	15	89	17.0
" 8.	87	978	9.0	26	130	20.0
" 10.	90	1360	6.0	16	114	14.0
March 3.	63	1112	5.7	21	59	35.0
MEAN.	99	1264	7.8	18	97	18.56

As neither the bacillus of typhoid fever nor coli communis are gelatine liquefying, it is interesting to note that the proportion of non-liquefying colonies is much less in the filtered than in the raw water.

TABLE I.—General Statistics.

RUN No.	1	2	3	4	5	6	7	8	9
Days Run	51	75	33	30	49	22	24	44	38
" Tested	15	50	25	19	24	5	0	2	3
Per ct. Days Tested	29.4	66.6	76.0	63.3	49.0	22.7	0.0	4.5	8.0
Gals. Filt by Tank, (approx.)	87,149	152,755	67,320	62,200	99,226	43,860	44,064	71,808	62,016
Gals. per Acre, (approx)	106,800,000	187,200,000	82,500,000	74,500,000	121,600,000	53,750,000	54,000,000	88,000,000	76,000,000
Initial Rate, (gal. per acre.)	1,920,000	1,880,000	2,500,000	2,000,000	1,800,000	2,000,000	1,800,000	2,000,000	2,000,000
Days in bringing to Normal (2,500,000 gallon rate).	34	½ day only	at once.	1	4	2½	6		

AVERAGE BACTERIAL RESULTS FOR EACH RUN.

		1	2	3	4	5	6	7	8	9
Raw Water:	Highest	1400	3700	2707	1486	2560	450		2620	545
" "	Lowest	145	149	186	280	164	158		456	100
" "	Mean	430	718	1032	924	1009	250		1538	374
Filtered "	Highest	835 or 370	157	497	115	326	25		37	17
" "	Lowest	4	26	24	22	20	15		30	5
" "	Mean	138	45	118	57	84	20		34	12
Mean Bacterial Removal		68.0	93.76	88.5	93.83	91.7	92.0		97.8	96.8
Per cent. Days Tested		29.4	66.7	76.0	63.3	49.0	22.7		4.5	8.0

General average for the 143 tests made during the year, was

Raw. { H. 3700, L. 145, M. 807.1 }

Filtered, { H. 835 (exceptional.), L. 4, M. 74.7 }

Mean Bacterial Removal for the 143 Tests, 90.8 per cent.

RUN No. 1.

			Bacteria per cc.	
		Raw.	Filt.	% Removal.
September 23, 1895.	2d day.	170	370	.0
" 25, "	4th "	145	105	27.60
" 26, "	5th "	1400	835	40.36
" 27, "	6th "	575	265	53.10
October 2, "	11th "	293	193	34.13
" 4, "	13th "	195	59	69.74
" 5, "	14th "	240	55	77.09
" 6, "	15th "	185	52	71.90
" 8, "	17th "	177	16	90.96
" 9, "	18th "	283	44	84.45
" 12, "	21st "	452	53	88.28
" 28, "	37th "	853	4	99.53
" 29, "	38th "	591	5	99.15
" 30, "	39th "	377	5	98.68
" 31, "	40th "	520	6	98.85
	Totals,	6456	2067	
	Mean,	430	138	68.0

RUN No. 2.

November 13, 1895.	1st day.	505	13	97.42
" 14, "	2d "	778	30	96.14
" 15, "	3d "	1156	64	94.46
" 16, "	4th "	782	56	92.84
" 18, "	6th "	946	8	99.15
" 19, "	7th "	424	8	98.11
" 20, "	8th "	196	8	95.92
" 21, "	9th "	612	6	99.02
" 23, "	11th "	232	7	96.98
" 25, "	13th "	350	8	97.71
" 26, "	14th "	176	4	97.73
" 29, "	17th "	414	10	97.59
December 2, "	20th "	788	10	98.73
" 3, "	21st "	528	6	98.86
" 4, "	22d "	302	9	97.02
" 5, "	23d "	411	0	100.00
" 6, "	24th "	494	6	98.79
" 7, "	25th "	408	2	99.51
" 17, "	35th "	486	86	82.31
" 18, "	36th "	344	59	82.85
" 19, "	37th "	270	81	70.00

RUN No. 2, Continued.

			Bacteria per CC.		
			Raw.	Filt.	% Removal.
December	20, 1895.	38th day.	318	57	82.08
"	21, "	39th "	779	92	88 20
"	23, "	41st "	3210	95	97.04
"	24, "	42d "	3700	157	95.76
"	25, "	43d "	2468	104	95.79
"	26, "	44th "	1542	76	95.07
"	28, "	46th "	1614	110	93.18
"	30, "	48th "	1564	93	94.06
"	31, "	49th "	1301	52	96 00
January	1, 1896.	50th "			
"	2, "	51st "	761	77	89.88
"	3, "	52d "	620	40	93.55
"	6, "	55th "	378	44	88.36
"	7, "	56th "	407	59	85.51
"	8, "	57th "	544	32	94.12
"	9, "	58th "	675	56	91.70
"	10, "	59th "	555	55	90.09
"	11, "	60th "	253	28	88.93
"	13, "	62d "	285	26	90.88
"	14, "	63d "	149	55	63.10
"	16, "	65th "	164	56	65.86
"	17, "	66th "	159	39	75.47
"	18, "	67th "	210	45	68.57
"	20, "	69th "	459	65	85.84
"	21, "	70th "	188	48	74.47
"	22, "	71st "	241	31	87.14
"	23, "	72d "	221	73	66.83
"	24, "	73d "	778	41	94.73
"	25, "	74th "	1320	29	97.81
"	27, "	75th "	442	26	94 12
		Totals,	35911	2242	
		Mean,	718	45	93.73

RUN No. 3.

		BACTERIA PER CC.		
		Raw.	Filtered.	% Removal.
January 28, 1896.	1st day.	2707	497	81.64
" 29, "	2d "	2019	459	79.27
" 30, "	3d "	1066	343	67.83
" 31, "	4th "	1163	249	79.59
February 1, "	5th "	1457	242	83.39
" 3, "	7th "	1292	116	91.02
" 4, "	8th "	1227	66	94.62
" 5, "	9th "	1716	118	93.12
" 6, "	10th "	1887	130	93.11
" 7, "	11th "	1156	114	91.14
" 8, "	12th "	1201	145	87.93
" 9, "	14th "	1292	113	91.25
" 11, "	15th "	730	68	90.69
" 12, "	16th "	946	27	97.15
" 13, "	17th "	794	56	92.95
" 14, "	18th "	420	29	93.10
" 15, "	19th "	1294	39	96.99
" 17, "	21st "	506	36	92.89
" 18, "	22d "	709	27	96.19
" 21, "	25th "	535	36	93 27
" 24, "	28th "	413	34	91.77
" 25, "	29th "	292	25	91.44
" 26, "	30th "	465	55	88.17
" 27, "	31st "	334	35	89.52
" 28, "	32d "	186	24	87.10
	Totals......	25807	2983	
	Mean.......	1032	118	88.57

RUN No. 4.

		BACTERIA PER CC.		
		Raw.	Filtered.	% Removal.
March 2, 1896.	2d day.	475	28	94.10
" 3, "	3d "	1010	49	95.15
" 4, "	4th "	995	65	93.47
" 5, "	5th "	944	46	95.13
" 6, "	6th "	646	60	90.71
" 7, "	7th "	1288	55	95.73
" 9, "	9th "	1083	56	94.83
" 10, "	10th "	992	57	94.25
" 11, "	11th "	1155	101	91.26
" 12, "	12th "	1486	43	97.11
" 13, "	13th "	1050	85	91.81
" 14, "	14th "	899	115	87.21
" 16, "	16th "	781	87	88.86
" 17, "	17th "	528	64	87.88
" 18, "	18th "	280	48	82.85
" 19, "	19th "	784	24	96.94
" 20, "	20th "	896	22	97.54
" 22, "	22d "		29	
" 24, "	24th "	1380	49	96.45
" 25, "	25th "	900	57	93.67
	Total........	17572	1140	
	Mean.......	924	57	93.83

RUN No. 5.

			Bacteria per cc.		
			Raw.	Filt.	% Removal.
March	31, 1896.	1st day.	2404	326	86.44
April	1, "	2d "	2560	201	92.15
"	2, "	3d "	2480	212	91.45
"	3, "	4th "	2016	223	88.94
"	5, "	6th "	1036	109	89.48
"	6, "	7th "	1462	144	90.15
"	7, "	8th "	940	102	89.15
"	9, "	10th "	806	68	91.56
"	10, "	11th "	738	23	96.88
"	11, "	12th "	430	50	88.37
"	13, "	14th "	1846	33	98.21
"	15, "	16th "	906	32	96.47
"	16, "	17th "	1324	85	93.58
"	17, "	18th "	718	48	93.32
"	18, "	19th "	506	50	90.12
"	20, "	21st "	344	37	89.25
"	21, "	22d "	164	55	66.44
"	22, "	23d "	328	43	86.87
"	23, "	24th "	912	30	96.71
"	27, "	28th "	274	22	91.97
"	29, "	30th "	182	35	98.08
May	5, "	36th "	988	45	95.44
"	13, "	44th "	274	21	92.33
"	16. "	47th "	584	20	96 57
		Totals,	24222	2034	
		Mean,	1009	84	91.7

RUN No. 6.

May	20, 1896.	2d day.	158	20	87.34
"	21, "	3d "	206	21	89.81
"	22, "	4th "	268	25	90.67
"	25, "	7th "	170	20	88.24
"	27, "	9th "	450	15	96.67
		Totals,	1252	101	
		Mean,	250	20	92.00

RUN No. 7.

		Bacteria per cc.		
		Raw.	Filtered.	% Removal.
June 12, 1896.	3d day.		15	

RUN No. 8.

		Bacteria per cc.		
		Raw.	Filtered.	% Removal.
July 10, 1896.	7th day.	655		
" 16, "	13th "	2620	30	98.85
" 20, "	17th "	456	37	91.89
	Totals......	3076	67	
	Mean.......	1538	34	97.79

RUN No. 9.

		Bacteria per cc.		
		Raw.	Filtered.	% Removal.
September 15, 1896.	30th day.	478	17	96.44
" 16, "	31st "	100	14	86.00
" 22, "	37th "	545	5	
	Totals......	1123	36	
	Mean.......	374	12	96.8

Dates of Tests.	Allegh'y River at Freeport. (Feet.)	Chlorine Parts per 100,000.	Bacteria per Cubic Centimeter.	Typhoid Cases in Pittsburg 3 weeks later.	Dates of Cases.	Remarks.
1895.					1895.	
Sept. 23.	2.0	......	170	10	Oct. 13. " 14.	
" 24.	2.7	......	......	10	" 15.	
" 25.	1.3	......	145	8	" 16.	
" 26.	1.2	......	1400	3	" 17.	
" 27.	1.0	... .	575	15	" 18.	
" 28.	0.9	......	......	2	" 19.	
" 29.	0.8	......	......	15	" 20.	
" 30.	0.9	......	......		" 21.	
Oct. 1.	0.6	......	......	8	" 22.	
" 2.	0.6	......	293	4	" 23.	
" 3.	....	......	......	2	" 24.	
" 4.	0.5	1.94	195	10	" 25.	
" 5.	0.6	......	240	4	" 26.	
" 6.	0.7	......	185	5	" 27.	
" 7.	0.7	......	......		" 28.	
" 8.	0.6	......	177	7	" 29.	
" 9.	0.5	......	283	6	" 30.	
" 10.	0.5	......	......	9	" 31.	
" 11.	0.5	......	......	5	Nov. 1.	
" 12.	0.5	......	452	11	" 2.	
" 13.	0.5	......	......	6	" 3.	
" 14.	0.4	......	......		" 4.	
" 15.	0.5	......	......	9	" 5.	
" 16.	0.5	......	......	...	"	
" 17.	0.5	......	......	4	" 7.	
" 18.	0.5	......	......	5	" 8.	
" 19.	0.4	......	......	8	" 9.	
" 20.	0.5	......	......	6	" 10.	
" 21.	0.4	......	......		" 11.	
" 22.	0.4	......	......	4	" 12.	
" 23.	0.3	......	......	5	" 13.	
" 24.	0.3	3.10	......	2	" 14.	
" 25.	0.3	......	......	4	" 15.	
" 26.	0.3	......	......	9	" 16.	
" 27.	0.3	......	......	8	" 17.	
" 28.	0.3	......	853		" 18.	
" 29.	0.5	......	591	2	" 19.	
" 30.	0.5	......	377	9	" 20.	
" 31.	0.5	......	520	1	" 21.	
Nov. 1.	0.5	......	......	3	" 22.	
" 2.	0.7	......	......	3	" 23.	
" 3.	0.8	......	......	2	" 24.	
" 4.	0.9	......	......		" 25.	
" 5.	0.9	4.07	......	4	" 26.	
" 6.	1.0	......	......	5	" 27.	

Dates of Tests.	Allegh'y River at Freeport. (Feet.)	Chlorine Parts per 100,000.	Bacteria per Cubic Centimeter.	Typhoid Cases in Pittsburg 3 weeks later.	Dates of Cases.	Remarks.
1895.					1895.	
Nov. 7.	0.9	......	......	...	Nov. 28.	
" 8.	0.9	......	......	4	" 29.	
" 9.	0.9	......	......	7	" 30.	Rain Nov. 9th.
" 10.	0.8	......	......	4	Dec. 1.	
" 11.	1.3	......	......		" 2.	
" 12.	4.1	......	......	5	" 3.	

RUN No. 1.—Total cases, 253; average cases per day, 5.4.

" 13.	3.7	......	505	2	Dec. 4.	
" 14.	3.0	......	778	4	" 5.	
" 15.	2.5	......	1156	2	" 6.	
" 16.	2.0	......	782	4	" 7.	
" 17.	1.8	......	......	8	" 8.	
" 18.	1.7	......	946		" 9.	
" 19.	1.5	......	424	1	" 10.	
" 20.	1.4	......	196	5	" 11.	Rain.
" 21.	1.4	......	612	3	" 12.	
" 22.	1.4	......	......	3	" 13.	
" 23.	1.6	......	232	5	" 14.	Rain.
" 24.	2.0	......	......	4	" 15.	
" 25.	3.4	......	350		" 16.	
" 26.	6.7	......	176	5	" 17.	
" 27.	9.2	......	......	6	" 18.	
" 28.	9.3	......	......	5	" 19.	
" 29.	7.6	......	414	2	" 20.	
" 30.	6.0	......	......	1	" 21.	
Dec. 1.	4.9	......	......	2	" 22.	
" 2.	4.5	......	788		" 23.	Rain.
" 3.	5.9	......	528	2	" 24.	
" 4.	7.4	......	302	1	" 25.	
" 5.	7.2	......	411	3	" 26.	
" 6.	5.4	......	494	3	" 27.	
" 7.	4.4	......	408	5	" 28.	
" 8.	4.0	......	......	10	" 29.	
" 9.	3.9	......	......		" 30.	
" 10.	3.7	......	......	9	" 31.	
" 11.	3.2	......	......	...	1896. Jan. 1.	
" 12.	2.7	1.56	......	4	" 2.	
" 13.	2.3	1.56	......	3	" 3.	
" 14.	2.1	1.74	......	...	" 4.	
" 15.	2.1	1.56	......	5	" 5.	
" 16.	1.7	1.74	......		" 6.	
" 17.	2.3	1.56	486	3	" 7.	
" 18.	2.3	......	344	2	" 8.	
" 19.	2.0	. ...	270	2	" 9.	
" 20.	2 4	2.22	318	2	" 10.	

Dates of Tests.	Allegh'y River at Freeport. (Feet.)	Chlorine Parts per 100,000.	Bacteria per Cubic Centimeter.	Typhoid Cases in Pittsburg 3 weeks later.	Dates of Cases.	Remarks.
1895.					1896.	
Dec. 21.	3.0	2.52	779	2	Jan. 11.	
" 22.	6.6	......	......	4	" 12.	
" 23.	9.5	2.61	3210		" 13.	
" 24.	9.0	2.23	3700	3	" 14.	
" 25.	8.4	2.81	2468	3	" 15.	
" 26.	8.4	1.64	1542	4	" 16.	
" 27.	11.6	......	......	...	" 17.	
" 28.	15.7	1.74	1614	4	" 18.	
" 29.	13.4	......	......	4	" 19.	
" 30.	11.3	1.26	1564		" 20.	
" 31.	10.0	1.06	1301	2	" 21.	
1896.						
Jan. 1.	9.5	......	......	4	" 22.	
" 2.	8.9	0.97	761	7	" 23.	
" 3.	7.6	0.97	620	7	" 24.	
" 4.	6.9	......	......	6	" 25.	
" 5.	5.0	......	......	15	" 26.	
" 6.	3.8	0.97	378		" 27.	
" 7.	4.0	0.97	407	...	" 28.	
" 8.	3.8	0.77	544	5	" 29.	
" 9.	4.3	1.26	675	2	" 30.	
" 10.	4.3	1.35	555	5	" 31.	
" 11.	4.2	1.56	253	...	Feb. 1.	
" 12.	4.4	......	......	...	" 2.	
" 13.	4.4	1.45	285	...	" 3.	
" 14.	4.0	1.45	149	9	" 4.	
" 15.	3.8	1.35	......	5	" 5.	
" 16.	3.2	1.35	164	6	" 6.	
" 17.	3.1	1.06	159	11	" 7.	
" 18.	2.8	1.35	210	2	" 8.	
" 19.	2.6	......	......	7	" 9.	Rain.
" 20.	3.0	1.84	459		" 10.	
" 21.	3.5	1.74	188	4	" 11.	
" 22.	3.5	1.84	241	4	" 12.	
" 23.	3.6	1.84	221	4	" 13.	Rain.
" 24.	4.0	2.13	778	3	" 14.	Rain.
" 25.	8.0	2.32	1320	5	" 15.	
" 26.	10.6	......	......	6	" 16.	
			RUN No. 2.—	260 ; average cases per day, 3.9.		
" 27.	9.6	1.64	442	6	Feb. 17.	
" 28.	8.4	......	2707	1	" 18.	
" 29.	7.3	0.97	2019	2	" 19.	
" 30.	7.0	1.26	1066	...	" 20.	
" 31.	6.0	1.26	1163	...	" 21.	
Feb. 1.	5.5	1.26	1457	4	" 22.	
" 2.	7.3	......	......	...	" 23.	

Dates of Tests.	Allegh'y River at Freeport. (Feet.)	Chlorine Parts per 100,000.	Bacteria per Cubic Centimeter.	Typhoid Cases in Pittsburg 3 weeks later.	Dates of Cases.	Remarks.
1896.					1896.	
Feb. 3.	10.5	1.35	1292	3	Feb. 24.	
" 4.	12.3	1.26	1227	4	" 25.	
" 5.	11.7	1.06	1716	2	" 26.	
" 6.	10.4	1.06	1887	6	" 27.	
" 7.	12.1	0.97	1156	3	" 28.	
" 8.	12.0	0.67	1201	2	" 29.	
" 9.	10.0	......	......	5	Mar. 1.	
" 10.	9.6	0.77	1292	3	" 2.	
" 11.	7.6	0.83	730	4	" 3.	
" 12.	6.7	0.87	946	4	" 4.	
" 13.	6.0	0.77	794	4	" 5.	
" 14.	9.9	1.06	420	3	" 6.	
" 15.	10.2	1.06	1294	3	" 7.	
" 16.	9.8	......	......	...	" 8.	
" 17.	8.6	0.87	506	3	" 9.	
" 18.	7.3	0.87	709	7	" 10.	
" 19.	7.0	0.97	......	7	" 11.	
" 20.	6.1	0.87	......	4	" 12.	
" 21.	5.5	0.97	535	4	" 13.	
" 22.	5.0	......	......	5	" 14.	
" 23.	4.3	......	......	...	" 15.	
" 24.	4.3	1.35	413	3	" 16.	
" 25.	4.0	1.35	292	2	" 17.	
" 26.	......	......	465	3	" 18.	
" 27.	4.3	1.26	334	2	" 19.	
" 28.	4.2	1.35	186	...	" 20.	
" 29.	5.0	1.35	......	2	" 21.	
			RUN No. 3.—	95 ; average cases per day, 3.5.		
Mar. 1.	7.2	......	......	3	Mar. 22.	
" 2.	8.9	1.16	475	...	" 23.	
" 3.	8.0	0.97	1010	2	" 24.	
" 4.	6.5	0.77	995	3	" 25.	
" 5.	5 2	0.87	944	2	" 26.	
" 6.	5.0	0.97	646	7	" 27.	
" 7.	5.1	0.97	1288	2	" 28.	
" 8.	5.9	......	......	1	" 29.	
" 9.	7.7	1.06	1083	1	" 30.	
" 10.	8.0	1.16	992	3	" 31.	
" 11.	7.5	0.87	1155	1	Apr. 1.	
" 12.	6 9	0.97	1486	4	" 2.	
" 13.	5.6	0.97	1050	...	" 3.	
" 14.	5.3	1.06	899	4	" 4.	
" 15.	4.7	......	......	...	" 5.	
" 16.	4.4	1.06	781	2	" 6.	
" 17.	4.2	1.06	528	3	" 7.	
" 18.	4 1	1.16	280	...	" 8.	

Dates of Tests.	Allegh'y River at Freeport. (Feet.)	Chlorine Parts per 100,000.	Bacteria per Cubic Centimeter.	Typhoid Cases in Pittsburg 3 weeks later.	Dates of Cases.	Remarks.
1896.					1896.	
Mar. 19.	4.5	......	784	4	Apr. 9.	
" 20.	5.7	1.84	896	2	" 10.	
" 21.	5.5	1.74	......	...	" 11.	
" 22.	5.2	......	......	...	" 12.	
" 23.	7.1	1.70	......	2	" 13.	
" 24.	6.2	1.50	1380	2	" 14.	
" 25.	6.0	1.45	900	...	" 15.	
" 26.	7.1	1.40	......	...	" 16.	
" 27.	12.5	1.21	....	...	" 17.	
" 28.	12.5	. ..	.....	2	" 18.	
" 29.	13.5	......	......	...	" 19.	
" 30.	19.1	0.77	......	6	" 20.	

RUN No. 4.— 56 ; average cases per day, 2.8.

" 31.	20.2	0.38	2404	1	Apr. 21.	
Apr. 1.	19.0	......	2560	6	" 22.	
" 2.	17.5	0.48	2480	3	" 23.	
" 3.	16.5	0.48	2016	...	" 24.	
" 4.	14.2	......	......	1	" 25.	
" 5.	12.1	......	1036	...	" 26.	
" 6.	10.5	0.29	1462	1	" 27.	
" 7.	9.6	0.48	940	..	" 28.	
" 8.	8.9	......	......	3	" 29.	
" 9.	8.0	0.77	806	3	" 30.	
" 10.	7.4	0.67	738	4	May 1.	
" 11.	7.4	......	430	3	" 2.	Rain.
" 12.	9.4	......	......	...	" 3.	
" 13.	10.5	0.87	1846	3	" 4.	
" 14.	10.4	0.77	......	3	" 5.	
" 15.	10.4	0.67	906	1	" 6.	
" 16.	9.8	0.67	1324	3	" 7.	
" 17.	9.0	0.67	718	4	" 8.	
" 18.	8.2	0.67	506	...	" 9.	
" 19.	7.5	......	......	...	" 10.	
" 20.	6.9	......	344	1	" 11.	
" 21.	6.9	......	164	2	" 12.	
" 22.	7.7	......	328	2	" 13.	
" 23.	7.0	......	912	2	" 14.	
" 24.	6.1	......	......	8	" 15.	
" 25.	6.0	......	......	1	" 16.	
" 26.	6.1	......	......	...	" 17.	
" 27.	6.0	......	274	5	" 18.	
" 28.	5.5	......	......	...	" 19.	
" 29.	5.2	......	182	4	" 20.	
" 30.	5.2	......	......	2	" 21.	
May 1.	4.9	......	......	1	" 22.	
" 2.	4.6	......	......	3	" 23.	

Dates of Tests.	Allegh'y River at Freeport. (Feet.)	Chlorine Parts per 100,000.	Bacteria per Cubic Centimeter.	Typhoid Cases in Pittsburg 3 weeks later.	Dates of Cases.	Remarks.
1896.					1896.	
May 3.	5.5	......	......	...	May 24.	
" 4.	6.2	......	......	3	" 25.	
" 5.	5.6	......	988	1	" 26.	
" 6.	5.0	......	......	4	" 27.	
" 7.	4.5	......	......	2	" 28.	
" 8.	4.0	......	......	3	" 29	
" 9.	3.7	......	......	3	" 30.	
" 10.	3.3	......	......	...	" 31.	
" 11.	3.1	.....	......	1	June 1.	
" 12.	3.0	......	......	3	" 2.	
" 13.	3.0	......	274	4	" 3.	
" 14.	2.8	......	......	...	" 4.	
" 15.	2.8	......	......	2	" 5.	
" 16.	2.7	......	584	2	" 6	
" 17.	2.4	......	......	...	" 7.	
" 18.	2.4	......	......	2	" 8.	
RUN No. 5.— 100; average cases per day, 2.7.						
" 19.	2.3	......	......	1	June 9.	
" 20.	2.2	......	158	2	" 10.	
" 21.	2.2	......	206	8	" 11.	
" 22.	2.1	......	268	2	" 12.	
" 23.	2.0	......	......	2	" 13.	
" 24.	......	......	......	...	" 14.	
" 25.	1.9	......	170	2	" 15.	
" 26.	1.7	......	450	1	" 17.	
" 27.	1.7	......	......	...	" 18.	
" 28,	1.7	......	......	...	" 19.	
" 29.	3.8	......	......	1	" 20.	
" 30.	3.3	......	......	..	" 21.	
" 31.	2.8	......	......	3	" 22.	
June 1.	2.6	......	......	...	" 23.	
" 2.	3.0	......	......	...	" 24.	
" 3.	3.7	......	......	1	" 25.	
" 4.	3.0	......	......	1	" 26.	
" 5.	2.6	......	......	1	" 27.	
" 6.	2.3	......	......	...	" 28.	
" 7.	2.1	......	......	4	" 29.	
" 8.	2.7	......	......	1	" 30.	
" 9.	2.9	......	......	3	July 1.	
RUN No. 6.— 33; average cases per day, 2.7.						
" 10.	3.7	......	......	2	July 2.	
" 11.	5.3	......	......	1	" 3.	
" 12.	5.4	......	......	...	" 4.	
" 13.	4.3	......	......	...	" 5.	
" 14.	3.4	......	......	2	" 6.	

Dates of Tests.	Allegh'y River at Freeport. (Feet.)	Chlorine Parts per 100,000.	Bacteria per Cubic Centimeter.	Typhoid Cases in Pittsburg 3 weeks later.	Dates of Cases.	Remarks.
1896.					1896.	
June 15.	3.0	......	......	...	July 7.	
" 16.	2.7	......	......	4	" 8.	
" 17.	2.7	......	......	4	" 8.	
" 18.	2.3	......	......	4	" 9.	
" 19.	2.7	......	......	...	" 10.	
" 20.	3.0	......	......	...	" 11.	
" 21.	2.9	......	......	...	" 12.	
" 22.	3.1	......	......	3	" 13.	
" 23.	3.0	......	......	7	" 14.	
" 24.	3.0	......	......	2	" 15.	
" 25	5.3	......	......	2	" 16.	
" 26.	9.5	......	......	...	" 17.	
" 27.	7.6	......	......	2	" 18.	
" 28.	5.3	......	......	...	" 19.	
" 29.	4.6	......	......	6	" 20.	
" 30.	3.9	......	......	1	" 21.	
July 1.	3.5	......	......	12	" 22.	
" 2.	3.0	......	......	8	" 23.	
" 3.	2.7,	......	......	4	" 24.	

RUN No. 7.— 64, average cases per day, 4.

" 4.	2.5	......	......	4	July 25.	
" 5.	2.5	......	......	...	" 26.	
" 6.	3.1	......	......	6	" 27.	
" 7.	4.4	......	......	8	" 28.	
" 8.	4.0	......	......	4	" 29.	
" 9.	3.4	......	......	1	" 30.	
" 10.	3.3	......	665	3	" 31.	
" 11.	3.0	......	......	1	Aug. 1.	
" 12.	2.8	......	......	1	" 2.	
" 13.	3.4	......	......	4	" 3.	
" 14.	2.6	......	......	9	" 4.	
" 15.	3.8	......	......	3	" 5.	
" 16.	8.8	......	2620	7	" 6.	
" 17.	6.0	......	......	11	" 7.	
" 18.	3.9	......	......	4	" 8.	
" 19.	3.2	......	......	...	" 9.	
" 20.	2.7	......	456	5	" 10.	
" 21.	2.9	......	......	10	" 11.	
" 22.	3.3	......	......	10	" 12.	
" 23.	3.4	......	......	10	" 13.	
" 24.	3.9	......	......	9	" 14.	
" 25.	6.5	......	......	9	" 15.	
" 26.	6.5	......	......	...	" 16.	
" 27.	5.4	......	......	7	" 17.	
" 28.	6.0	......	......	7	" 18.	
" 29.	8.6	......	......	10	" 19.	

Dates of Tests.	Allegh'y River at Freeport. (Feet.)	Chlorine Parts per 100,000.	Bacteria per Cubic Centimeter.	Typhoid Cases in Pittsburg 3 weeks later.	Dates of Cases.	Remarks.
1896.					1896.	
July 30.	8.5	......	......	3	Aug. 20.	
" 31.	9.5	......	......	4	" 21.	
Aug. 1.	9.1	......	......	7	" 22.	
" 2.	7 6	......	......	...	" 23.	
" 3.	7.1	......	......	4	" 24.	
" 4.	6.4	......	......	10	" 25.	
" 5.	4.0	......	......	18	" 26.	
" 6.	3.0	......	......	9	" 27.	
" 7.	2.4	......	......	6	" 28.	
" 8.	3.0	......	......	5	" 29.	
" 9.	3.0	......	......	...	" 30.	
" 10.	3.0	......	......	6	" 31.	
" 11.	3.9	......	......	8	Sept. 1.	
" 12.	5.8	......	......	5	" 2.	
" 13.	5.2	......	......	5	" 3.	
" 14.	5.5	......	......	4	" 4.	
" 15.	5.0	......	......	2	" 5.	

RUN No. 8.— 239 : average cases per day, 6.3.

" 16.	3.9	......	......	...	Sept. 6.	
" 17.	3.3	......	......	8	" 7.	
" 18.	2 8	......	......	7	" 8.	
" 19.	2 5	......	......	7	" 9.	
" 20.	2.2	......	......	6	" 10.	
" 21.	2.0	......	......	10	" 11.	
" 22.	9.9	......	......	9	" 12.	
" 23.	0.9	......	......	...	" 13.	
" 24.	1.9	......	......	8	" 14.	
" 25.	2.0	......	.....	5	" 15.	
" 26.	1.9	......	......	9	" 16.	
" 27.	1.9	......	......	5	" 17.	
" 28.	1.6	......	......	4	" 18.	
" 29.	1.5	......	......	4	" 19.	
" 30.	1.4	......	.....	...	" 20.	
" 31.	1.3	......	......	6	" 21.	
Sept. 1.	......	......	......	4	" 22.	

RUN No. 9.— 92 ; average cases per day up to September 2d, 6.6.

CHEMICAL AND BACTERIOLOGICAL ANALYSES COMPARED.

DATE.	Free Ammonia. Parts per 100,000.			Albumenoid Ammonia. Parts per 100,000.			Bacteria. Per cc.		
	Raw.	Filtered.	Per cent. Removal.	Raw.	Filtered.	Per cent. Removal.	Raw.	Filtered.	Per cent. Removal.
December 4, 1895.	0008	0013	Increase	0134	0076	43.29	302	9	97.02
" 12, "	00016			0124					
" 13, "		00008	50.00		0004	96.77			
" 17, "		0008			0053		486	86	82.31
" 18, "	0013		38.46	0114		53.51	344	59	82.85
" 23, "	0038			0102			3210	95	97.04
" 24, "		0034	10.53		0052	49.02	3700	157	95.76
" 30, "		0018			0096		1564	93	94.06
" 31, "	0018		None	0170		43.53	1301	52	96.00
January 7, 1896.	0006			0080			407	59	85.51
" 8, "		0008	Increase		0066	17.50	544	32	94.12
" 20, "	0022			0068			459	65	85.84
" 21, "		0010	54.55		0046	32.35	188	48	74.47
" 28, "	00420			0164			2707	497	81.64
" 29, "		00134	68.10		0066	59.76	2019	459	79.27
February 4, "	00214			0120			1227	66	94.62
" 5, "		00106	50.47		0064	46.67	1716	118	93.12
" 11, "	00160			0066			730	68	90.69
" 12, "		00134	16.25		0044	33.33	946	27	97.15
Mean.	00178	00129	27.53	01142	00571	50.0	1285	117	90.89

RELATIVE HARDNESS OF RAW AND FILTERED WATERS.

CRAIG STREET—1895-96.

DATE.	Parts per 100,000.	
	Raw.	Filtered.
September 23, 1895.	4.99	5.96
" 25, "	4.99	6.55
October 3, "	6.24	4.99
" 24, "	6.86	7.33
November 5, "	7.33	7.80
December 12, "	3.90	4.36

It is believed that the increased hardness, observed at first in the filtered water, was due in great part to the lime of the cement tank walls. The sand contained only a trace of calcium carbonate.

METHOD USED FOR BACTERIOLOGICAL CONTROL OF FILTER WORK.

AT CRAIG ST.

MAKING UP 2% NEUTRAL AGAR FOR CULTURE WORK.

3 gms. of meat extract, 5 gms. of salt, 10 gms. of Witte's Peptone, and 100 cc. of water were stirred together cold, in a 12 oz. beaker, until all soluble matters were dissolved. The solution was then rinsed into a 1000 cc. graduated cylinder, made up to the mark and mixed.

10 cc. was titrated with 0.5 per cent. Na O H solution using phenol-phtalein indicator. We calculated from this how much 5 per cent. Na O H solution was needed to make the rest of the solution neutral and then added it. The bouillon was then rinsed into a flask, 20 gms. of finely chopped agar-agar added and the whole heated in a steam sterilizer until the agar was disintegrated. We then cooled the solution to 70° C., and added the white of an egg beaten up with 50 cc. of water, and returned the flask to the sterilizer where it remained with occasional shaking until separation occurred. We then filtered as rapidly as possible into three or four 12 oz. erlenmeyer flasks. These were covered with several 5 inch filter papers held down by rubber bands, and were given 15 minutes in the steam sterilizer as soon as they were filled. This operation was repeated on the two succeeding days.

PREPARING CULTURE TUBES.

Strong $6 \times \frac{1}{2}$ inch test tubes were rinsed with soda (if greasy), then with water, H Cl, and water successively. After draining and drying, they were stoppered with cotton wadding, care being taken to have the stoppers uniform and free from seams, and of about $1\frac{1}{2}$ inch depth with plenty of projecting top.

We then placed the tubes upright in a wire basket and heated to 150° C., in an air oven for one hour. Cooled.

FILLING THE CULTURE TUBES.

5 cc. of melted culture medium was carefully poured into each tube and the tube quickly closed and replaced in the wire basket. When all were filled the basket containing them was heated for 15 minutes in the steam sterilizer. This operation was repeated on each of the two following days.

PREPARATION OF PETRI DISHES.

The thoroughly cleaned and dried Petri dishes were sterilized 1 hour at 150° C. When cool, if to be transported to the filter house, they were clamped with rubber bands and carefully wrapped up. Cultures were all made at the filter house.

MAKING THE CULTURES.

A platinum crucible, with a well fitting cover, was heated red hot and allowed to cool. A $\frac{1}{8}$ inch platinum tube was also heated red hot and cooled on asbestos. Four culture tubes were placed in 1 inch of water in a metal cup and the water was heated to boiling. By shaking once or twice the agar became uniformly fluid.

In the meantime, the covered platinum crucible was carefully filled with the filtered water and re-covered. A tube of melted agar was withdrawn, the stopper charred and the contents cooled to about 100° F., by rolling in the hand. 1 cc. of water was then quickly dropped in with the usual precautions, and after mixture with the agar, the whole was poured into a sterile Petri dish. A duplicate culture was then made. The crucible and platinum tube having been again sterilized as before, a sample of the raw water was taken and duplicate cultures of 0.5 cc. each were made.

Development took place in a well lighted room at a temperature designed to be kept between 70° and 85° F. When the latter temperature was much exceeded the cultures were rejected. Counting took place after three to five days.

METHODS FOR CHEMICAL ANALYSES.

Free and Albumenoid Ammonia:—500 cc. were used without filtration. The alkaline permanganate and other reagents were made according to Wanklyn.

Chlorine:—50 or 100 cc. were titrated with standard silver nitrate.

Hardness:—The soap test made essentially as Wanklyn directs.

CULTURE MEDIA USED FOR BACTERIOLOGICAL WORK.

AT CRAIG ST.

FULLER'S ACID AGAR.

3	grams	of	Armour's meat extract.
5	"	"	salt.
10	"	"	Witte's peptone.
15	"	"	agar-agar.
60	"	"	glycerine.
18	cc.	"	normal hydrochloric acid.
1000	cc.	"	water.

This was used until Dec. 17th, 1895, when its use was abandoned because it gave low results.

NEUTRAL 2% AGAR.

3	grams	of	Armour's meat extract.
5	"	"	salt.
10	"	"	Witte's peptone.
20	"	"	agar-agar.
1000	cc.	"	water.

This neutral agar was used for all tests after Dec. 17, 1895.

10% NEUTRAL GELATINE.

3	grams	of	Armour's meat extract.
5	"	"	salt.
10	"	"	Witte's peptone.
100	"	"	French gelatine.
1000	cc.	"	water.

The 10% gelatine culture medium was used for comparative tests after Dec., 1895.

PITTSBURG, Feb. 18th, 1897.

J. O. Handy, Treas. in % with The Sand Filtration Fund.

DR.

To contributions received from July 25th, 1895, to February 18th, 1897	$720 00	$720 00

CR.

By cash paid for constructing filter and house for same and for carrying on tests, etc.	$687 81	
By cash on hand	32 19	720 00

LIST OF CONTRIBUTORS TO THE SAND FILTRATION FUND.

Engineers (civil, mechanical and electrical)	$ 48 00
Lawyers	61 00
Physicians	50 00
Business men	448 00
Editors	30 00
City officials and other employees	20 00
Clergymen	13 00
Women	15 00
Politicians and others	35 00
Total	$720 00

LIST OF EXPENSES.

COST OF FILTER TANK.

Common labor	$ 56 39
Plasterers	36 75
Pipe fittings	13 98
Sewer pipe	13 89
Sand for filter	11 25
Sand for concrete	2 75
Foreman's expenses	9 00
Paint	4 75
Hauling	2 25
Foundation for tank (18 inch concrete)	(given)
Cement (Atlas Portland, 4 bbls.)	(given)
Expanded metal	(given)
Total	$151 01

COST OF BUILDING AND FITTINGS.

Lumber	$109 15
Tin-roof and hardware	54 31
Laboratory supplies	24 08
Stove and oven covers	3 25
Tools	2 35
Doors and sashes	13 23
Glazing	15 00
Pipe fittings for gas and water	10 23
Brick	2 00
Plumbing	49 05
Sundries	43 88
Foreman's wages	61 61
Carpenter's wages	36 63
Common labor	5 38
Building permit	3 00
Total	$433 15
By cash paid for assistant's services in making tests, 13 weeks at $7.00	81 00
By cash paid for signs and printing	22 65
Sum of all expenses	$687 81

The paper was discussed by Messrs. Garrigues, Camp, Stahl, Holland and others.

The meeting adjourned at 11 P. M.

A. G. McKENNA,
Secretary C. S.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

The regular monthly meeting of the Engineers' Society of Western Pennsylvania took place in the lecture room of the Society's house, 410 Penn Avenue, Pittsburg, Pa., Tuesday evening, March 16th, 1897. Meeting called to order at 8:30, Mr. Emil Swensson in the chair, and 40 members and visitors being present.

Minutes of last monthly meeting, as well as those of special meeting, March 2d, read and approved.

REPORT OF BOARD OF DIRECTION.

THE PRESIDENT—In regard to the communication from Mr. Flad, President of the St. Louis Society, I may state that copies of the resolution passed by this Society were sent to Senator Quay, Congressman Dalzell and Congressman Stone, and all have answered saying they will act on the bill when it comes up.

The committee appointed to draft resolutions on the death of Mr. Stevenson and the Committee on Power had no report to make.

The committee on Pavement could only report progress, Mr. Kirk being still away from the city.

THE PRESIDENT—Again it becomes our sad duty to chronicle the departure of one of our members, Mr. Morehead, the venerable President of the Monongahela Navigation Co., from this vale of trials and tribulations. Has any one anything to offer?

Moved by Mr. Shellenberg and seconded by Mr. Davis that a committee be appointed to draw up a memorial. Carried.

The President appointed as committee, Col. T. P. Roberts, Mr. Charles Davis and Mr. Shellenberg.

The Secretary here read the names of five applicants for membership, which the Board of Direction recommend to the Society for balloting at the next regular meeting.

Election of New Members.—The following names, Lawrence Barr, William A. Conner, Thomas A. Gillespie, Edward L. Lee, John McLeod, Albert Pancoast, George C. Schade and John Vanderslice were presented for ballot, the President appointing as tellers Messrs. Lyons and White.

Thirty-two votes were cast for each candidate, and they were declared elected.

The President—Concerning the bequest of my distinguished countryman, Mr. Alfred Noble, some further information has come to my notice through the newspaper reports of the proceedings and testimony taken by the Court at the probating of the will. It seems that Mr. Noble did not give any detailed instructions regarding the conditions under which he wished the prizes awarded, in consequence of which there would possibly be some doubt and dispute over the manner of distribution of the money.

However, the testimony given by the executors, two engineers enjoying the intimate friendship of the testator, conclusively shows that Mr. Noble intended the money to be given to young men, having discovered something new and important under the different headings given in the will, thereby enabling them to put in practice their ideas, rather than to award the prizes to men already well established in their respective professions, and in no need of financial encouragement.

Another matter in connection with this legacy may be cause for some doubt and dispute, and that is, the legality of Swedish and Norwegian institutions acting as judges in awarding the prizes bequeathed in a testament written in Paris, France. The Courts of France may possibly claim jurisdiction in the matter, and a long drawn out fight be the result.

Be that as it may, a conclusion will be reached some day and the money will surely be available for the purpose intended,

and in the meantime it will be well for us to be thinking about capturing part of the yearly distribution of four to five hundred thousand dollars. I will now call on Mr. Engstrom for further explanation regarding the matter.

Mr. Engstrom—The latest news is to the effect that the Swedish Court, where the will was probated, declared itself competent to take testimony and probate the will on the ground that Mr. Noble was de facto a resident of Bofors, Sweden, although the testament was written during a temporary sojourn abroad. This is presumed to allay the fear of the French court mixing in the matter.

As to the prizes, it would probably have been better had Mr. Noble been a little more explicit, but the testimony also brought out the fact that he never was in the habit of giving detailed instructions about anything, only indicating in a general way what he wanted done, trusting his assistants to attend to the details, and leaving it entirely with them how it should be done. Thus the executors of the will are free to formulate the rules to the best of their judgment, and make them as broad as they were intended.

It is, by the way, very flattering for our profession that a man of Mr. Noble's business capacity, in disposing of his millions for prizes, open to the whole world, did not appoint business men or lawyers as executors of his will, but left it in the hands of the most trustworthy and wide-awake people he knew, two engineers.

The President—That being the case it is now open for us to make an effort to capture part, if not all, of this money.

NEW BUSINESS.

The President.—I beg to report my observations and comparisons made on a recent visit to the Boston Society of Civil Engineers. They have Annual Banquets, the same as we, the one this year being held the 9th of March at the Hotel Brunswick, and a custom of theirs, to invite representatives of other Engineering Societies, is in my judgment well worthy of

adoption. In my capacity of President of this Society, I was honored with an invitation and deemed it advisable to accept, and am very glad of it, as I learned a great many things, which, if you think them worth your consideration, can be of great benefit to our Society.

First, I may state that the Boston Society, which in the home of learned Societies is known as *The Society*, is as strong as ours, having a membership of about 430, and in activity they certainly surpass us. They have semi-monthly meetings, and in addition they have Saturday excursions nearly all the year round, with a dinner after the return from these excursions, after which they repair to their rooms for an informal discussion of what they have seen during the afternoon. The attendance at the meetings is always good, from 90 to 125 being present, especially at the excursions. One of the reasons for the large attendance, I believe, is their custom of bringing the plans and specifications of work in hand to the meetings for discussion, which idea, if adaptable to our conditions, would certainly make the interest in our meetings very much greater than now.

Their annual dues are only $8.00 for residents, $5.00 for non-residents, and the initiation fee is $5.00 ; this latter never being used for current expenses, but put into a permanent fund, now consisting of about $10,000, from which special expenditures are liquidated ; such as house furnishing, books, &c., for library, printing expenditures for banquets, excursions, etc., expenditures for invited guests, and similar matters.

The question naturally arises, how can they get so much for their money, and the answer is :

First, their Society is so well recognized and of such power in the city and state that traveling accommodations, etc., are obtained free, and second, that living, etc., is cheap in Boston, as, for example, the banquet menu, which was equally as good and of more courses than that we had at the Duquesne Club, only cost $2.00 per plate.

I mentioned that the Boston Society is well recognized and a power in the city and state. This was clearly proven several times during the banquet by the remarks of the speakers. It is to be noted that the speeches were not made by the members of the Society, but by the guests, several of whom were men of great prominence. Both private and corporate capital in New England seems to recognize in the Engineers not only its servants, but masters as well in their economical function, they being considered in the light of an economical brake on the expenditures of the various firms and companies employing them.

This point was nicely covered by President Clark, of the N. Y. N. H. & H. R. R., who made a (to the profession) very flattering speech that evening. He knew a great many of the nearly 200 Engineers present, and could testify to the sterling qualities, capabilities and integrity of the profession, and illustrated how it only through the assistance of the Engineers was possible for roads like his to carry out such extensive improvements as had lately been completed on his road in the face of hard times and with the strict economy necessary, and which had resulted in the material shortening of train time between New York and Boston.

That he is a true friend of the profession and fully appreciates the value of its work, is further illustrated by the sending of many of his engineers to Europe a year or two ago at the expense of the road and as its accredited representatives (an engineer told me this) to study railroading there, especially the station and terminal arrangements, with a view to adopting the same for his road.

In engineering matters affecting the safety, health and comfort of the public as well as the economical expenditure of public money, the standing and the efficiency of the Society and the individual Engineer is well established in New England, especially in Boston and its state, inasmuch as the profession is always represented on State and City committees and commis-

sions, in which engineering questions will come up for consideration. Yes, such legislative bodies are often created at the request of and by the pressure of our profession.

Notable among such commissions are the Metropolitan Water Commission, the Metropolitan Sewage Commission, the Metropolitan Park Commission, and the Metropolitan Rapid Transit Commission, which all will ultimately have an incalculably good effect on the safety, health and comfort of the population living in the Metropolitan district, of which Boston is the Hub. These commissions make it possible for the engineers to take up the study of these important questions on a broad and comprehensive basis instead of the former penny-wise and pound foolish manner necessary under existing conditions.

Even on matters, which at first blush seem rather foreign to our profession, the assistance of the Boston Society was requested, and that by a lawyer, a member of the profession which claims to know and understand all subjects. One of the speakers of the evening being the President of the Civil Service Commission, he endeavored to show how the bona-fide engineers would get protection against impostors by having the engineering employees of State and City examined in accordance with rules and questions formulated by the Boston Society; the members of the commission not being engineers, they would of course not attempt to make up such rules, but would as a matter of course request the assistance of the Boston Society.

In telling the above I hope I have succeeded in showing to you that the Boston Society is a recognized power at home both privately and publicly, both technically and politically, and a power for good and economy, and if I have also succeeded in creating in you a desire to emulate them, I would feel gratified beyond measure.

Now let us contrast ourselves with the Boston Society; let us look back and see what we have done and how our work and

suggestions have been received; what recognition we have got, what we have profited by it, collectively and individually.

I do not need to relate it in detail, as it is all well known history to you, but recall it in a general way: What was the fate of our road law on which so much thoughtful work was done? Pigeonholed. What recognition did we get for our extensive work on the Sanitation Committee, especially in regard to water supply and filtration? After all our work and expense were we in any way remembered when the Council of Pittsburgh appointed a filtration committee from among the citizens at large? No! And when this committee required engineering advice on the subject, did they engage home talent? No! How about the question of smoke prevention, did we conclude our discussions of the subject with anything tangible, anything of practical good to either the community, the Society, or to our individual members? No! It was a mere discussion of one of the local questions of the hour without any definite action as to remedies and their enforcement, etc.

What is the reason for such poor results from our labors? I believe it is because of our touchiness as to our professional dignity, and our fear of being mixed up in politics, and even straight business. As long as the subject keeps us within the scientific and professional boundaries we are all right, but when it comes to introducing and working for a law in the various legislative bodies, then we seem to be a failure. We cannot reach our greatest usefulness to the community and ourselves without coming in touch with politics when necessary to have our ideas embodied in laws, etc., and I see no reason why that cannot be done without contamination. Neither do I see any reason why we should refer business matters of public moment to the Chamber of Commerce or any other body; we should be in position to be heard ourselves and respectfully listened to. The safety, health, comfort and business prosperity of the citizens of this city and end of the State are as much dependent upon our profession as upon any other class of men, if not

more, which in itself is sufficient reason for us to take a very active part in the affairs of the community and State, and not simply do what we are told.

Why should not the Engineers Society of Western Pennsylvania be as well recognized in engineering matters, as, for example, the Chamber of Commerce, the Coal Exchange or the Rivermen's Association are in their respective domains? If you should be connected with some engineering work on the rivers around Pittsburg and should have occasion to call on the U. S. Engineers for advise, why should he not refer you to the Engineers Society as well as to the Coal and Rivermen, instead of the latter only?

If we wish to take the above mentioned active interest in public affairs affecting the welfare of Pittsburg and its surroundings, we can begin right now by taking decided action on the Dalzell bill relating to length of bridge spans over the Monongahela and Ohio rivers, among others, now before Congress or rather the Committee on Interstate Commerce. This bill, which I am informed is fathered by the Coal and Rivermen, was up before the last Congress also, but was not considered before the adjournment.

The bill is absurd in more ways than one, such as requiring all bridges to be at right angle to the current at all stages of water; requiring all spans to be through bridges and at the same time fixing minimum height of iron work over high water; but the prohibitory clause is the one requiring the channel span over the Monongahela river to be of not less than 800 feet opening, and over the Ohio river not less than 1,000 feet, which you all know not to be necessary as these rivers are mostly of less width by 200 to 300 feet.

This clause is prohibitory by reason of the enormous cost of such spans, as a new bridge would have to count on a greater prospective traffic than could be expected for a great many years at any point on these rivers, and you know capitalists do not invest their surplus for health or glory. It is not in our

purely professional capacity we should object, as such spans are not an impossibility for us to build, but in our combined capacity of engineers and business men, who know that their cost would prohibit such long spans from being built.

Mr. Wilkins—That is what the coal men want.

Mr. Shellenberg—Would it be possible for this Society to be represented in the Chamber of Commerce?

The President—I do not know what the Chamber of Commerce would do on such questions. Why should we be represented in that body? We are strong enough to represent ourselves.

Two weeks hence we will, at a special meeting of this Society, listen to a paper by Mr. E. K. Morse on the subject of said Dalzell bill. We will invite the Coal and Rivermen to be present at that meeting and will probably have some interesting discussion on the subject at the time. I hope our members will be out in full force.

I have very likely transgressed somewhat on your time, but having our Society so much at heart, I hope you will pardon me.

Mr. W. G. Wilkins then read the paper of the evening entitled "Electricity in Coal Mining," after which he showed a number of steriopticon views illustrating various types of electric locomotives, engines, pumps, etc., used in coal-mining.

ELECTRICITY IN COAL MINING.

BY W. G. WILKINS.

GENERAL OBSERVATIONS.

That the use of electricity as a power in mining operation is a success, both commercially and mechanically, seems to have been satisfactorily proven to many mine owners, judging from the number of mines in which it is used as a power for haulage and mining machines. Most of the mines where it is now in use report a great saving over hand labor in mining and

mules for haulage, but whether it is the power that would have made the largest saving over old methods is a debatable question, as advocates of compressed air claim, at least, equally, if not more, economical results with this medium. Reliable data by which the two systems may be compared is difficult to obtain, as the condition at the various mines using them are so different that the results are hardly comparable. There are, however, two points that seem to be in favor of the electric system rather than the compressed air; first, while compressed air will successfully accomplish all in the way of power that electricity can do, the latter has the added advantage of furnishing light; second, in a mine where electricity is used to operate mining machines, as well as locomotives, the work of both is done under the same pressure or voltage, and the same generating plant will furnish the power for both purposes. With compressed air the coal cutters are operated under a comparatively low pressure, from 60 to 80 pounds per square inch, and the compressed air locomotive requires a high pressure, 600 lbs. requiring a second compressor to compress the air used in the locomotives, and if the plant has a charging station in the mine some distance from the compressor, there must be a separate air main to the receiver, which must be sufficiently strong to withstand the high pressure, while with electricity the same conductor may furnish power for all classes of machinery. There are, however, advantages peculiar to each system, and the conditions at different mines vary so much that the problem must be solved for the particular mine under consideration. At one mine power may be wanted for mining machines only, or haulage only, while at another the power may be wanted for all purposes, mining machines, pumps, ventilating fans, and haulage. Where power is wanted for haulage only, there are points in favor of compressed air, as beyond the compressor plant and locomotive, the only requirement is good tracks on which to run the locomotive, while for electric haulage there is required the generating plant,

locomotives, good tracks, and in addition, trolley and feed wires, the extent of which will limit the extent of the haulage, while the compressed air locomotive can go any place in the mine where the tracks are solid enough, and having curves of sufficient radius to permit its operation.

Most of the plants that have been installed for mining purposes have been isolated plants to operate a single mine, and the direct current system has been the one used, with pressures of 220 or 500 volts. It would seem that there might be an advantage in several mines, situated at no great distance from each other, to combine and operate them with power from a single central power plant, which would result in a saving over the cost of operating several separate power stations. This method might also prove a good investment for capitalists to erect power stations and furnish mines with electric power at a rental which would prove remunerative and at the same time save first cost to the mines using the power. The advantage of a central power station was recognized by the Youghiogheny Coal Co., in the equipment of their five mines near Scott Haven, Pa. The power is carried about three miles to their No. 5 mine, which is the greatest distance from the power station, at which the power is used. This plant is operated by the direct current system, with an allowable percentage of loss in the lines of 10 per cent.

Since the successful operation of three phase alternating current motors has been accomplished, there is possibly a new field for central power stations for mining purposes, as this system will permit of an economical distribution of the current to greater distances than with the direct current. With this system it is possible to use generators of low voltage at the power station with step up transformers, which will permit the use of smaller conductors, thus reducing their cost, and at the various mine mouths the voltage can be reduced by the use of step down transformers to such a voltage as is consistent with safety.

In what follows it is not the intention to go into the theory of electricity, or into the details of the construction of dynamos, motors, and other electrical machinery, as many large volumes have been written on these subjects, but simply to touch on the practical features, far enough to enable the mining engineer to form an opinion as to whether the plant to be installed by the electrical engineer or contractor is well constructed and sufficient for the work it is to perform.

In fitting up a mine with electricity, as a power, the author would not advise the mining engineer to try and work up the plant in its smallest details, for electrical engineering is a specialty that has made great advances in the last few years, and there are probably very few mining engineers who have kept pace with this advancement. On the other hand there are very few electrical engineers who are also mining engineers and who are fully posted on the various requirements of mine work. It is better then, when the mining engineer has decided to install an electrical plant, to call in the services of an electrical engineer who is not in the employ of any of the electrical construction companies, but who is acquainted with the various devices of them all, and by working together the result will be more satisfactory than if either one alone had attempted the work.

If, however, it is preferred to make a contract for a complete plant with any of the construction companies, there should be a well defined specification and contract covered by a bond running a sufficient time, guaranteeing that for a given sum they will install a plant that they will do a certain specified work at a certain cost for operating and maintenance.

It should be borne in mind, that, in making such a contract the company making the guarantee will in all probabilty make the price for the work large enough to cover any contingencies that might arise, and which must be met before the guarantee can be made good.

SAFETY OF ELECTRICITY IN COAL MINES.

The question is frequently asked, "Is the use of electricity in coal mines safe?" If there is gas, even in small quantities, the answer is that it is dangerous and that some other form of power, such as compressed air should be used, from the use of which there is no possibility of an explosion of the gas. If there is no reason for the exclusion of electricity from the mine on this account, the question then arises, "Is there not danger to life by reason of the miners and mules coming into contact with the bare conductors?" In thin vein mines, where the roof is so low that the conductors are less than six feet from the floor, a higher voltage than 220 should not be used, but in thick vein mines, where the conductors can be placed high enough to be out of reach of the men, a voltage of 550 may be used; but if in any part of the mine it is necessary to place conductors for mining machines in easy reach, insulated wires should be used; this, of course, will not be possible for trolley wires. The author believes, however, that in the large majority of mines 220 volts should not be exceeded, and that 550 volts should not be used, unless the distance to which the power is to be carried is so great that the cost of a 220 volt plant would be prohibitory. The writer is aware that many plants have been installed with 550 volts pressure, but he believes from the number of accidents caused by this pressure that it should not be used, if it can be avoided.

EFFICIENCY OF ELECTRIC PLANTS.

The efficiency of an electric plant, considered separate and apart from the efficiency of the steam engine or other power plant used to actuate the generator, is the product of three factors, viz.: the efficiency of the generator, the efficiency of conductors, and the efficiency of the motor. In the best class of electric generators and motors, as now built, the loss is only about 10%, or each having an efficiency of 90%, the combined or coupled efficiency of the generator and motor will be $.90 \times .90$ or 81%. Now the loss in the line may be any amount that

may be decided upon, depending upon the size of the conductor used to transmit the current, and it follows that the total efficiency of the plant may be almost any desired efficiency less than 81%.

The usual allowable loss in conductors for mine work is taken at 10% to 15%, so that a plant with the line loss at 10% would have an efficiency of $.90 \times .90 \times 90 = 72.9\%$, which is comparatively high. It is not, however, always the cheapest plant, either in first cost or cost of operation, which has the highest efficiency.

For a given amount of power delivered to the motors, we must have a generator that will generate power in excess of that required by the motors, which excess will vary with the size of the conductor used to transmit that power from the generator to the motor, and the greater the line loss the greater must be the excess power developed by the generator, and the less the cost of the conductors the greater will be the cost of the generator. From this it will be seen that the plant of minimum first cost will be that in which the variation in cost of generators is the same as that in the cost of the conductors.

For the minimum first cost for a given pressure at the motor the efficiency decreases quite rapidly as the distance to which the power is transmitted increases, but the distance to which a given amount of power may be transmitted with a given efficiency varies directly as the electro-motive force used, the cost of installation remaining the same.

The electric plant which is the cheapest in the long run will be that in which the operating expenses, interest, and depreciation are a minimum, and for this plant there must be used a conductor of a certain size in which there is a certain amount of lost or waste energy.

Sir William Thomson's law states that, "The most economical area of conductor will be that for which the annual interest on capital outlay equals the annual cost of energy wasted."

Now the cost of the energy wasted will have a certain relation to the above mentioned items, interest, operating expenses, etc., and these items are so variable depending upon the location of the plant and other conditions, that contractors for electric mining plants and electrical engineers, do not as a rule, go into close estimates as to the plant of minimum first cost or that of least cost of operation, but have decided that for all practical purposes, in view of the fact that there is generally installed a plant with excess power for contingencies and extensions, it is sufficient to design a mining plant with an allowable line loss of 10% to 15%, depending upon the distance to which the power is to be transmitted.

TYPES OF GENERATORS FOR MINE WORK.

The generators that have been most frequently used for mine work have been of the bi-polar or four-pole type, belt driven by high speed automatic engines, the latter running at from 200 to 350 revolutions per minute, and the generators at from 500 to 700 revolutions at their normal output. The advocates of the bi-polar type claim the following advantages: it is the simplest form of dynamo in its practical construction, it needs no cross connections in the armature or commutator, requires but one pair of brushes and one pair of field coils, and simplifies the wire connection between the armature and field. The bi-polar type has been used for years for mine work and seems to have given satisfactory results. Latterly dynamos of the four-pole type have been quite largely used, and they have this advantage over the bi-polar type, that with armatures of the same diameter they may be wound to give a greater output while running at the same speed, and for a given output they need not be driven at so high a speed as the bi-polar type. Direct coupled generators are usually of the multi-polar pattern, with ring armatures of large diameter, running at slow speed, so far as the revolutions are concerned, but with about the same peripheral velocity as the smaller high speed type. This type of generator has not, so far, been very largely used for mine work. Figs. 1 and 2 show the general style of multipolar, belt driven generators.

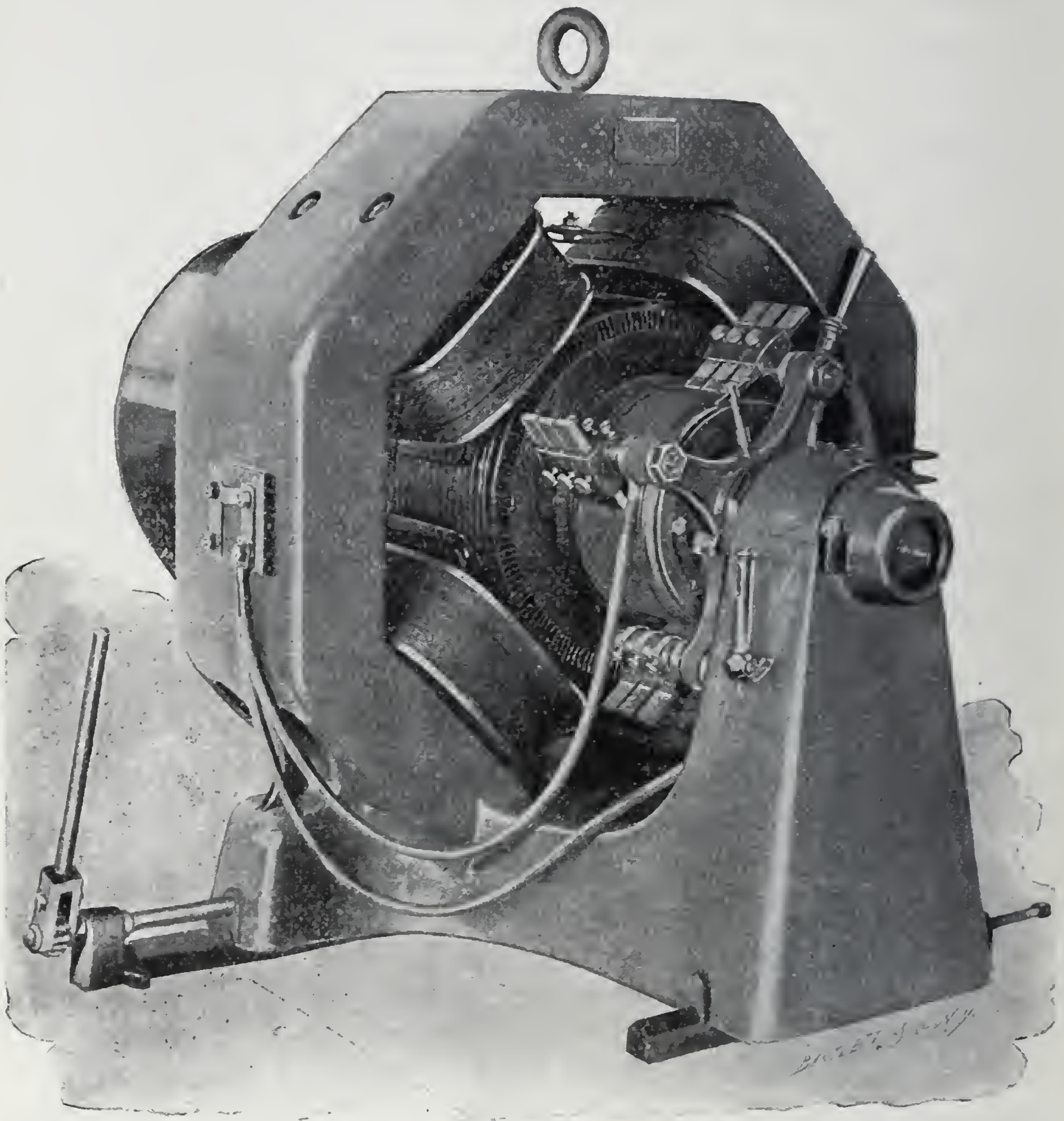


Fig. 1. Eddy Electric Manufacturing Co.'s Generator.

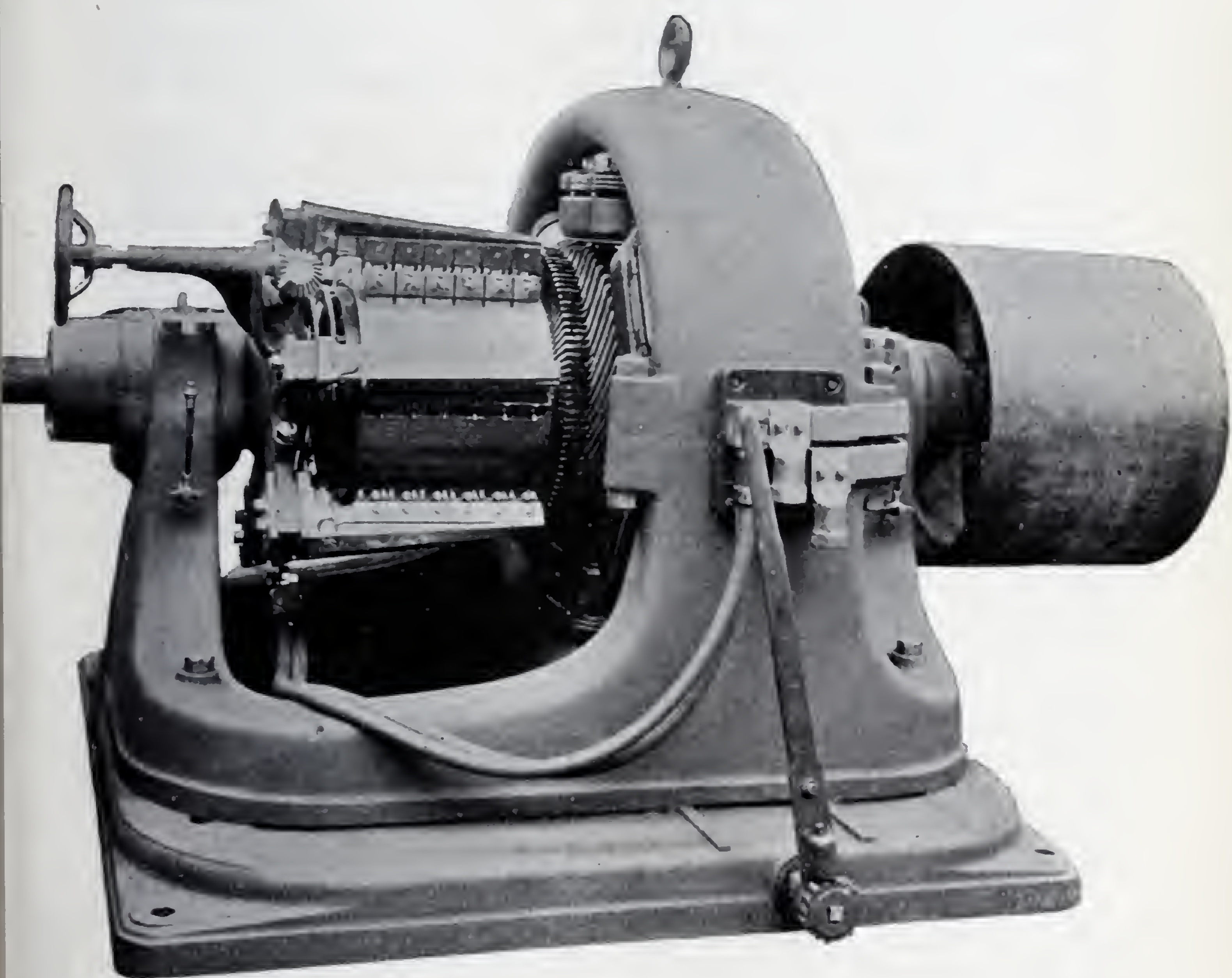


Fig. 2. Westinghouse Electric Co.'s Generator.

PRACTICAL HINTS REGARDING SELECTION OF A DYNAMO.*

The following by F. B. Crocker, while written with reference to electric light dynamos is equally applicable to the selection of a dynamo for mine purposes:

"One of the first questions an electrical engineer is called upon to decide is the selection of a dynamo for a certain plant. It depends largely upon circumstances in each particular instance, but there are certain general principles which apply to almost all cases.

"*Construction*—This should be of the most solid character, and first-class in every respect, including materials and workmanship.

"*Finish*—A good finish is desirable, first, because it indicates good construction, second, it stimulates the interest and pride of the attendant, and third, it shows the least dirt or neglect.

"*Simplicity*—The machine in all its parts should be as simple as possible, and any peculiar or complicated features should be avoided. These are sometimes successful, but should be well tried and proved before being accepted.

"*Attention*—The amount of attention required by a dynamo should be small. The screws, connections and other small parts should be arranged, so that they are not likely to become loose, and the delicate parts should not be exposed or liable to injury.

"*Handling*—The machine should be provided with an eye-bolt, or other means by which it can be easily lifted or moved without injury. It ought to be possible to take out the armature conveniently, by removing one of the bearings or top of the field magnet.

"*Interchangeability*—Machines should be made with interchangeable parts, so that a new piece, which will fit perfectly, can be readily obtained; for this reason, regular and established types are preferable to special or unsettled forms.

*From "Electric Lighting," by F. B. Crocker. Published by D. Van Nostrand Co., N. Y.

"*Regulation*—Some form of regulator should be provided by which the E. M. F., or current, can be reliably and accurately governed.

"*Capacity*—This should be ample in all cases. It is a very common mistake to underestimate the work required of a given machine, and even if it has sufficient power at first, the demands upon it are apt to increase, and finally overload it. No one is ever likely to regret choosing a dynamo having a reasonable margin of capacity, since these machines only consume power in proportion to the work they are doing. For example: a 25 Kilowatt generator would probably run with a 20 K. W. load more economically than a 20 K. W. machine with the same load.

"*Form*—The dynamo should be symmetrical, well proportioned, compact and solid in form. If it is either very tall or very flat, it is usually inconvenient and clumsy. No part should project excessively, or be awkwardly formed or arranged. The large and heavy portions should be placed as low as possible, to give greater stability. For the same reason, the shaft should not be high above the base, nor should it be so low that there is not ample room for the pulley or other attachment. A horizontal belt, for example, will sag and strike the floor if the pulley is very low.

"*Weight*—The common idea that it is desirable to have a very light dynamo is a mistake, when it is for stationary use. There is no advantage in a light machine, except portability; and it has the disadvantage of being less strong, less durable and less steady in running. A sufficient weight to make it thoroughly substantial is obviously of great benefit.

"*Cost*—It is also a mistake to select a cheap machine, since both the materials and workmanship required in a high quality dynamo or motor cost more than in almost any other machine of the same size and weight. It is an undeniable fact that there has been considerable trouble with electrical machinery owing to inferior construction.

"These suggestions as to selecting a dynamo or motor may be followed when it is possible to make merely a general examination of the machine, or even in case where it is only possible to obtain a drawing or description of it. But to make a complete investigation it is necessary to carry out a thorough test, and measure exactly its various constants.

"A satisfactory test cannot usually be made, however, until the machine is set up in place; and moreover it is not generally necessary if it is obtained from a reputable source."

TYPES OF ENGINES FOR ELECTRIC PLANTS.

One of the principal requirements for a steam engine used as a prime mover for an electric generator, is that it shall respond readily to the various conditions of the load, whether it is direct couple or belted. In the engines commonly used for electric work this is accomplished in two ways; first, by means of a governor acting on the throttle, the pressure, and consequently the speed, of the engine is increased or reduced; second, the throw or travel of the valve is varied, thus increasing or diminishing the number of expansions of the steam in the cylinder with a consequent variation in the mean effective pressure and speed. Engines of the first class are termed "throttling," and are now seldom used for electric plants; those of the second class are called "automatic," and may be subdivided into those having slide valves, which are generally high speed, and those with valves of the Corliss or rotary type, which are run at slow or medium speed. Automatic engines of the slide valve type are run at from 150 to 350 revolutions per minute, depending upon the size of the engine. Engines of the Corliss or drop cut-off type are very economical, so far as the consumption of steam is concerned, but the cut-off is not rapid enough to permit of the rapid speed that can be had with the positive cut-off used with the high speed slide valve type. While the piston speed in feet per minute in the two styles may be approximately the same, the number of revolutions in the drop cut-off must be less, usually from 50 to 150 per

minute, thus requiring a larger and more expensive engine for the same power. The type that has been most used for mine plants has been the automatic high speed, and they may be either simple or compound, non-condensing or condensing, horizontal or upright. Where fuel is a minor consideration, which is the case in coal mine plants, the class of engine that has been most largely used has been the simple, non-condensing automatic high-speed type, as the small additional cost of fuel used has been believed to be more than counterbalanced by the greater first cost of the compound condensing type. Fig. 3 is an example of this type of engine.

METHODS OF CONNECTING ENGINES WITH GENERATORS.

There are three methods of connecting the steam engine with the generator in plants having more than one unit. The first, and which up to the present has been most used in plants for mine work, has been to have each generator run by a separate engine, with belt from the pulley of generator to the driving wheel of the engine; second, to have each generator run by a separate engine with the main shafts directly coupled; the third method, is to have the engines with belts running to pulleys on a line shaft, and a second set of belts from the line shaft to the generator pulleys. In the first two methods where each generator is run by its own engine, the disadvantage is that should any engine break down the generator which it operates is thrown out of service, and vice versa, if the dynamo is stopped for repairs its engine must be thrown out, while in the third method, by a proper arrangement of friction clutches, any engine in the plant may drive any dynamo. One advantage of the direct coupled, aside from an increased efficiency, is the smaller power house required, while the third or counter shaft method requires the largest sized building, and the greatest capital outlay for this purpose. Fig. 4 shows a direct connected unit.

With the direct coupled engine the first cost is greater than the direct belted, both for engine and generator, as a di-

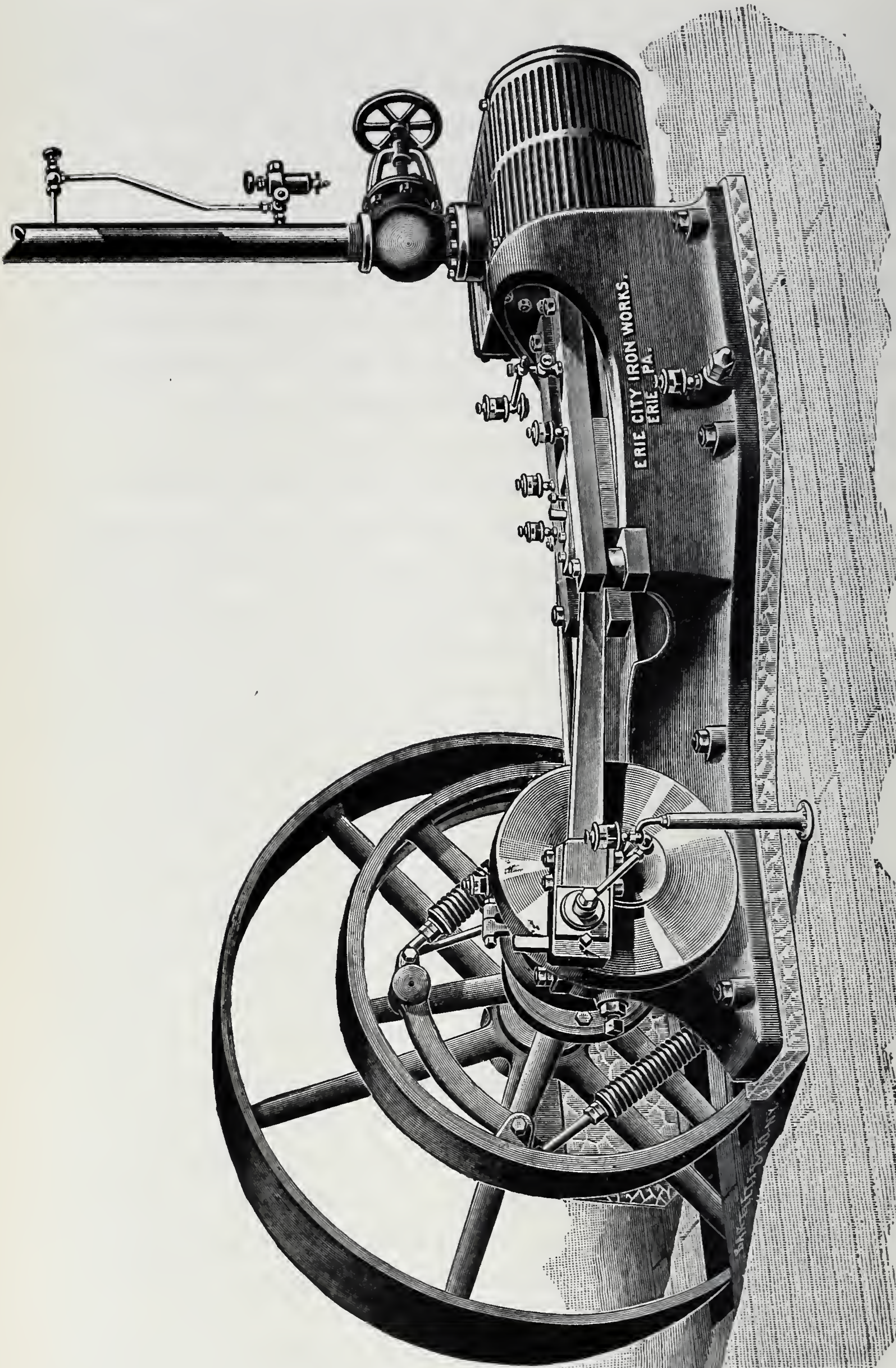


Fig. 3. Automatic High Speed Engine.

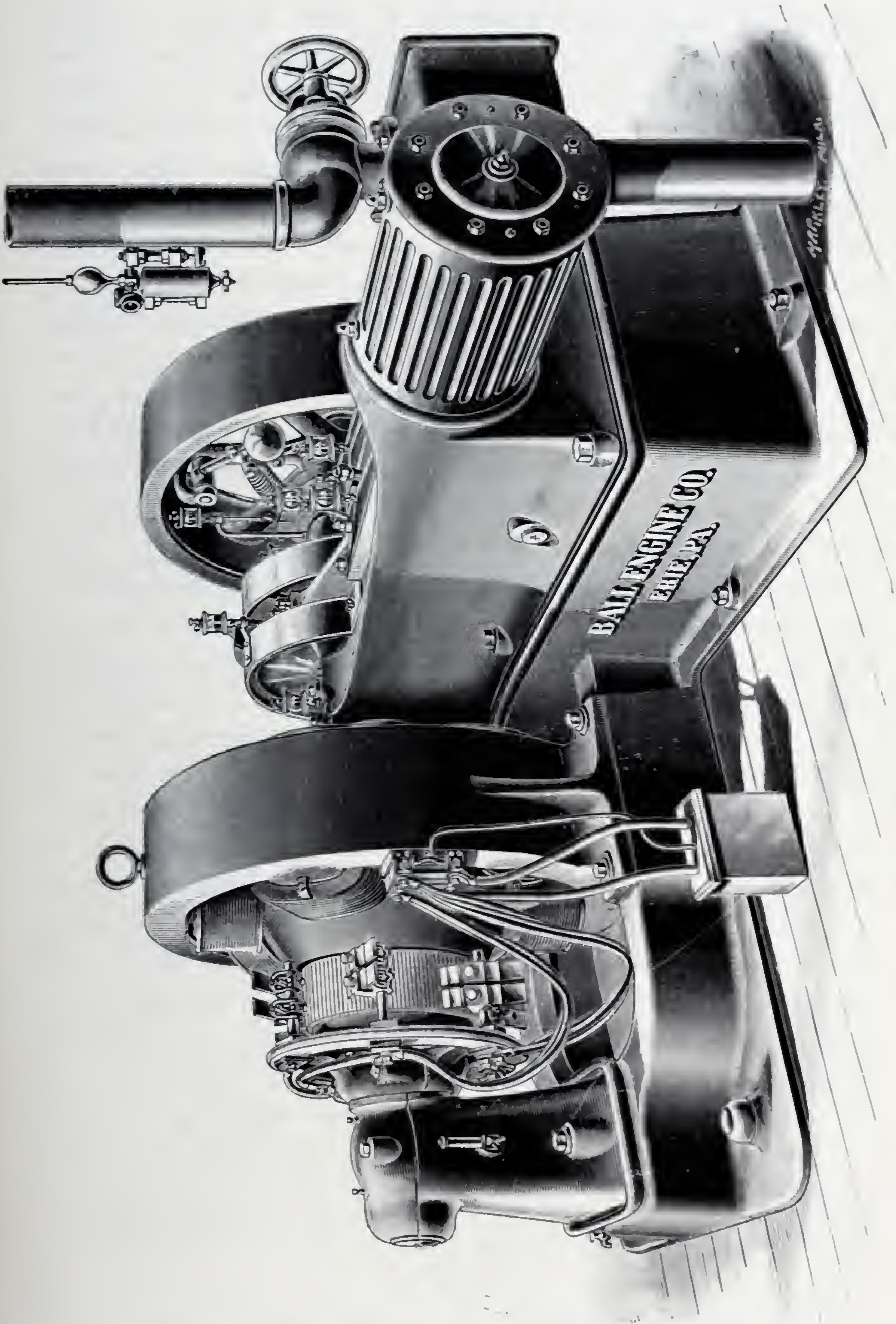


Fig. 4. Direct Connected Generator and High Speed Engine.

rect coupled generator is generally designed to give a certain amount of power at a slower speed than a direct belted for the same capacity, it must consequently be larger and more costly, and the slow speed engine which actuates it must also be correspondingly larger and higher in first cost than a high speed engine of the same horse power. This difference in cost is partially offset by the saving of the cost of belt, foundations, and the wear and tear on the fewer bearings required and an increased efficiency of about 5%. In some of the later plants installed these considerations have outweighed the increased first cost, and direct coupled compound condensing engines have been used, notably the plant of the Colorado Fuel & Iron Co., where the engine used is direct coupled of the vertical cross compound marine type, designed by E. F. Williams and built by William Todd & Co., of Youngstown, O. The cylinders are $11 \times 9 \times 15$ developing 150 H. P. at 250 revolutions, non-condensing.

As to the relative efficiency of belted or direct coupled generators, Prof. Francis B. Crocker says, "The relative efficiency depends greatly upon conditions; but in general the former is more efficient at light load, and the latter at or near full load. A careful test made at the Edison Station, '3d District,' Brooklyn, N. Y., showed that at about the full load of 250 H. P. the electrical output was 87% of the total indicated horse power for direct coupling, and 81% for belting. At about one-third load they were both the same at 70%, and at one-fifth load belting gave 60% and direct coupling only 35% efficiency. The obvious conclusion from this test, which agrees with results obtained in other cases, is that direct coupling is 'about 5%' more efficient between one-half and full load, but below one-third load belting gives higher efficiency, and for very small loads it may be far more efficient than direct coupling."

BELTING.

The most satisfactory belt for running the dynamo, all

things considered, is an endless leather belt made of the best quality of belting leather. There are three thicknesses of leather used for belting; single, light double and double; the latter will prove the most serviceable, and is worth the extra cost. The formulæ for determining the width of a belt to tramsmit a given power are all empirical, and those of different authorities vary considerably. A common rule is that a belt one inch wide, running at a speed of 1,000 feet per minute, will transmit one horse-power, or

$$H.\ P. = \frac{v\ w}{1000} : \quad W = \frac{1000\ H.\ P.}{v} \quad \text{for single belts,}$$

and if the efficiency of a double belt is 10-7 that of a single belt, we will have

$$H.\ P. = \frac{v\ w}{513} : \quad W = \frac{513\ H.\ P.}{v} \quad \text{for double belts.}$$

These formulæ are on the supposition that there are 180 degrees of contact between the belt and the pulley, and if the contact it less than 180 degrees, the values of W as obtained above should be divided by the following constants for the various angles given :

a—90°	100°	110°	120°	130°	140°	150°	160°	170°	180°	200°
c—.65	.70	.75	.79	.83	.87	.91	.94	.97	1.00	1.05

In order that the belt shall run true, care must be taken that the dynamo and engine shafts are parallel, and that a line joining the centers of the driving and driven pulleys shall be at right angles with both shafts. The belt when new, should be just long enough to reach, when the dynamo is slid up on the sliding rails as close to the engine as possible, so that as the belt stretches, the dynamo can be pushed back from time to time as the proper running of the belt requires.

FOUNDATIONS.

In laying out foundations for engines and generators of belted units, care must be taken to have the center lines of the two foundations exactly parallel and the proper distance apart, and also that the tops should be horizontal, so that when the

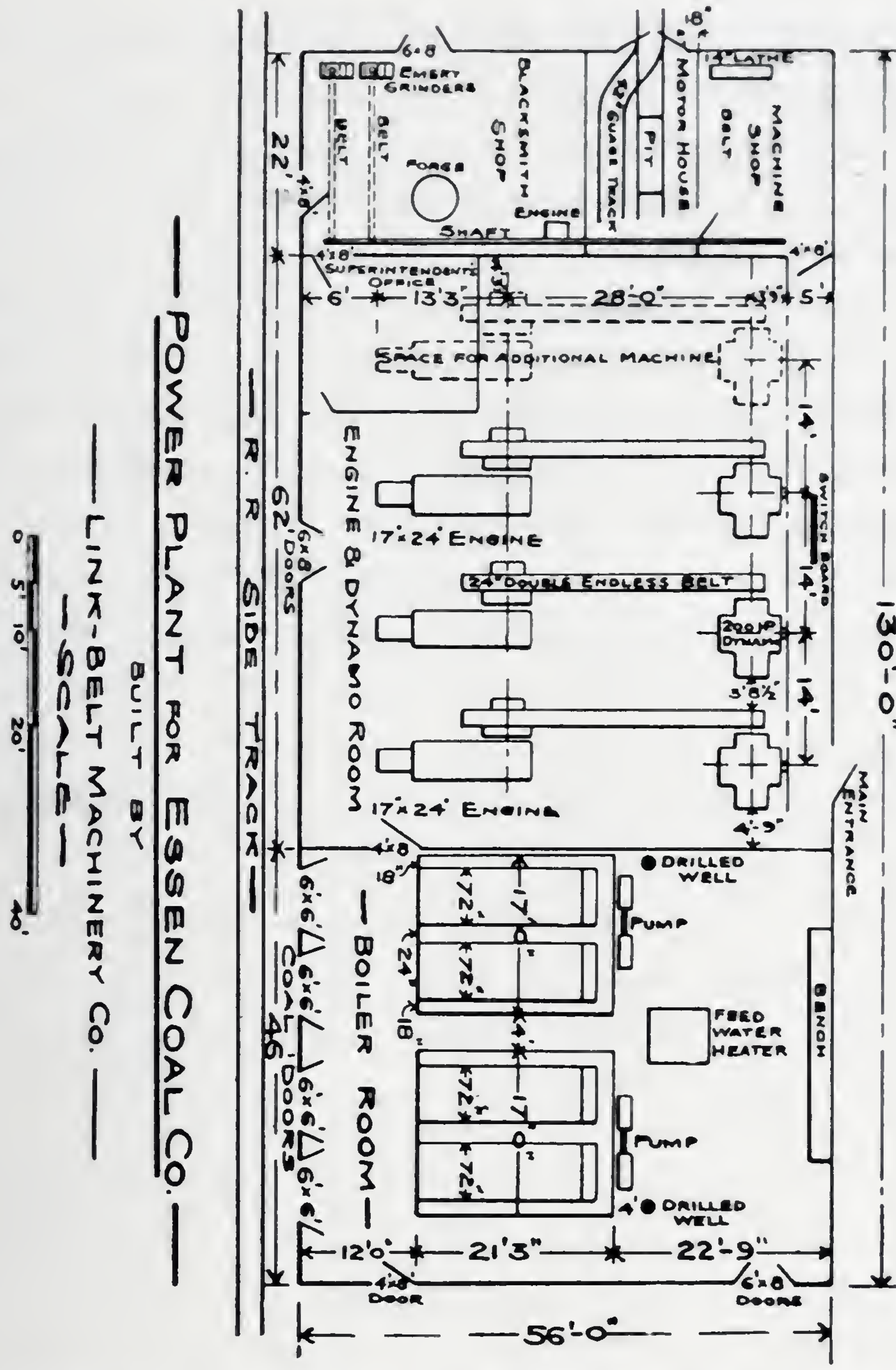
machinery is set up there may be no trouble in getting the belt to run properly. With direct coupled units the foundation for engine and dynamo should be one solid piece of masonry, as there will be less liability of one part of the foundation settling and throwing undue strain on the coupling, than with separate foundations for engine and dynamo.

The machinery foundation should be entirely separate and disconnected from the building foundations, which will prevent very materially any vibrations being transmitted from the machinery to the building.

ARRANGEMENT OF POWER HOUSE.

The arrangement of the machinery in the power house should be such that all parts are easily accessible to the engineer, while at the same time there should be no waste room which would add unnecessarily to the size and cost of the building. The generators should occupy a room independent of the boiler room, so as to prevent as much as possible the carrying of dust and ashes from the boilers to the machine room, which should be as free from dirt and dust as possible. As said before, the size of the power house will depend upon whether belted or direct coupled engines and generators are used. With direct belted machines the engine and generator shafts will be about 20 feet and upwards, center to center, a common rule being to make the distance three times the diameter of the larger pulley, and the shape of the building will depend upon the number of the machines, and whether they are set crosswise or lengthwise of the building. If the boilers and generators are all under one roof the location of the building should allow of the coal for the boilers being taken from the pit mouth or tipple direct to the boiler house and dumped in front of the boilers without having to be shoveled by hand.

Fig. 5 shows the arrangement of the power house of the Essen Coal Company at Essen, Pa., and the following is a description of it by T. W. Sprague, condensed from the "Engineering and Mining Journal":



No. 5.

"The power house itself is excellent in material and construction, in its general design and arrangement. It is a building 130 feet long by 56 feet wide, steel frame, with corrugated iron covering. It is set on a 15-inch brick foundation, and the ceiling of the dynamo and engine room is sheathed to prevent trouble from the moisture of condensation.

"The west end of the building contains four Russell tubular boilers, each 60 inches in diameter and 18 feet long, and containing 64 tubes $3\frac{1}{2}$ inches in diameter. The boiler room extends along nearly 50 feet of the length of the build-

ing, occupying the full width. The boilers are set with sufficient space in front for a coal storage supply, coal being thrown directly from cars on a spur track running parallel with, and close to the building, and leaving a wide space behind them for the feed pumps, feed-water heater, etc., which are reached through a passageway between the two batteries. In the space behind the boilers is also a pump furnished by the Hall Steam Pump Company for deep well work. The water supply or a part of it, at present comes from these wells, one 129 feet deep, one 160 feet and one 180 feet. The water is raised on the compressed air system, the pump or compressor being a tandem machine with an 8-inch stroke. The water is pumped into two boilers, 3 feet by 22 feet, which are used as supply tanks, being placed about 16 feet above the feed pumps. They also serve as settling tanks and give sufficient head to fill the boilers, when no steam is available.

"The engine room, which occupies the central portion of the building through its full width is 63 feet long. It contains three automatic Corliss engines, made by the Russell Manufacturing Company, Massillon, O., with cylinders 17 inches by 24 inches, running at a speed of 153 revolutions per minute. They are set on brick foundations, and have 10-foot fly-wheels. With the steam pressure usually carried, 90 to 100 pounds, these engines will develop something over 200 H. P. each. They drive three 150 kilowatt bi-polar generators made by the Link Belt Machinery Company, of Chicago, of the 'Independent' mining type, wound for 275 volts and running at 510 revolutions per minute. These 200 H. P. generators are probably the largest bi-polar machines in use to-day. They are compound wound and provided with self-oiling bearings, ventilated armatures and other improvements. Space is left for a fourth unit of the same size which may be added when the work is further extended underground. The engines are set at 30-foot centers from the generators, and 18-inch double endless standard belts are used.

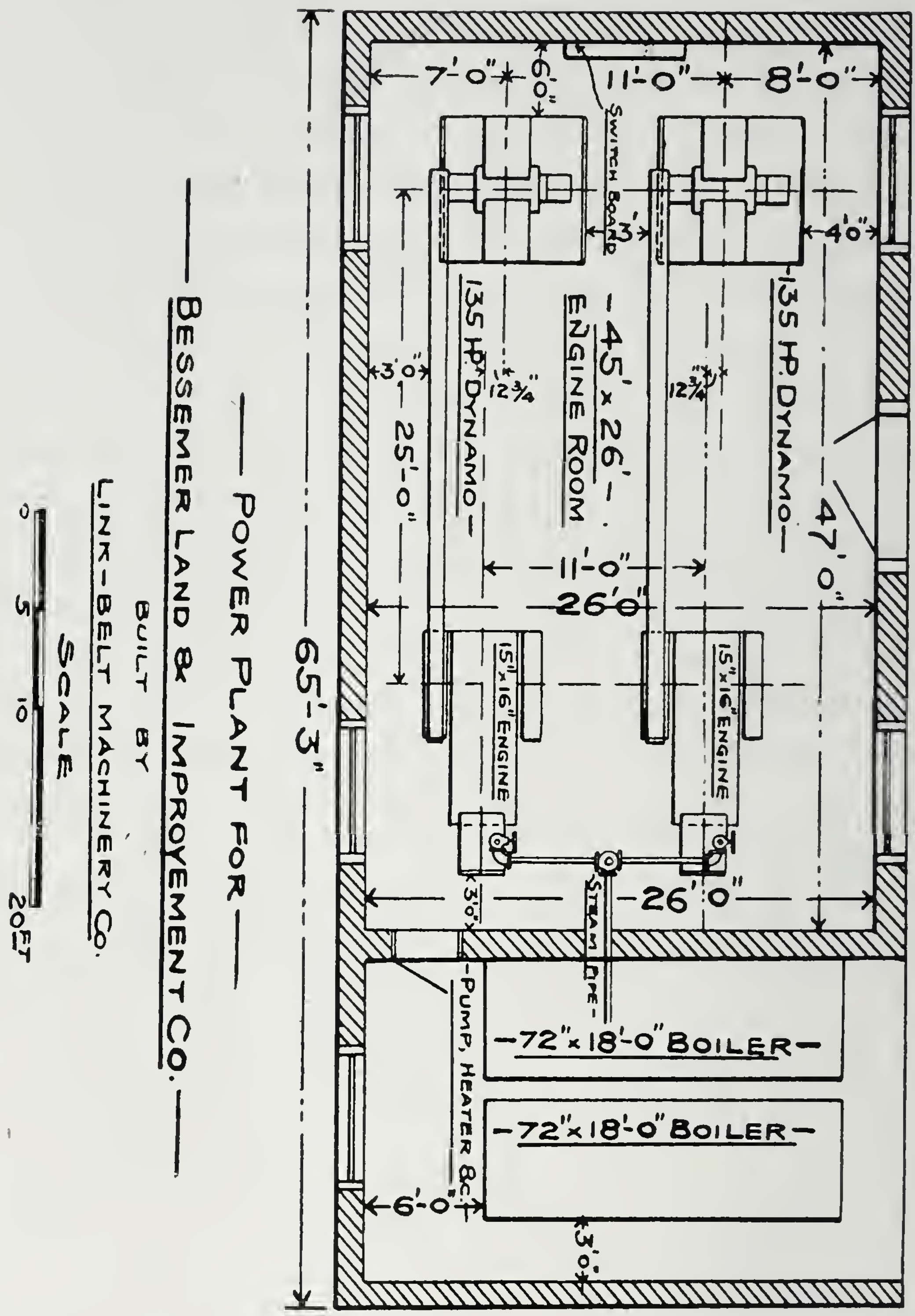
"The station instruments are mounted on a marble switch-board, also furnished by the Link Belt Machinery Company, which company took the contract for the entire plant, delivered and erected. The switch-board carries two Westinghouse circuit breakers, three Weston round pattern ammeters, one voltmeter of the same make, together with the field rheostats and usual switches. Wurts' lightning arresters are placed in each of the two mains leading to the two mines, and also at the bank mouths. One set of arrresters is also placed on the long stretch of feeders between the power house and No. 2 mine. The trolley line running outside between the two mines is independently controlled by a single pole switch in the power house. This stretch is comparatively little used, and is normally 'dead.'

"The remainder of the power house building is divided into three rooms, a blacksmith and machine shop, a locomotive house and a store room, containing a lathe and some other power tools.

"The locomotive room is large enough to hold on its two spur tracks the two 80 H. P. locomotives now in use. It is provided with pits for getting at the under parts of the machines and an overhead crane for lifting heavy parts."

Fig. 6 gives the plan of a power house designed by the Link Belt Machinery Co., for the Bessemer Land and Improvement Co. The plant consists of two units of 135 H. P. generators operated by direct belted engines with 15 inch × 16 inch cylinders, and two 72 inch × 18 foot tubular boilers. The whole arrangement of the plant is very compact, occupying a building 28 feet × 65 feet, 3 inches, but having, however, ample room for access to all parts of the machinery.

These two examples are sufficient to give an idea of the proper arrangement of a power house for mining purposes.



No. 6.

DETERMINATION OF ELECTRICAL AND MECHANICAL UNITS FOR POWER PLANT.

The following table will assist in determining the total electrical horse power required by the generators, and the total mechanical horse power required to run them, for an electrical plant with any desired efficiency in the system of from 40 to 81%. The table is based upon assumed efficiencies of 90% each in generator and motor:

EFFICIENCY IN ELECTRICAL POWER TRANSMISSION.

1	2	3	4	5	6
Mechanical H. P. required at Motor Shaft.	Elec. H. P. transmitted to Motor Shaft.	Per cent. loss in Conductor.	Elec. H. P. required in Generator.	Mechanical H. P. to be delivered at Generator Pulley.	Efficiency of whole system in per cent.
1.00	1.1111	0.0	1.1111	1.2346	81.00
1.00	1.1111	1.0	1.1223	1.2470	80.19
1.00	1.1111	2.0	1.1337	1.2597	79.38
1.00	1.1111	3.0	1.1454	1.2727	78.57
1.00	1 1111	4.0	1.1574	1.2860	77.76
1.00	1.1111	5.0	1.1696	1.2995	76.95
1.00	1.1111	6.0	1.1721	1.3134	76.14
1.00	1.1111	7.0	1.1947	1.3275	75.33
1.00	1.1111	8.0	1.2077	1.3419	74.52
1.00	1.1111	9.0	1.2210	1.3567	73.71
1.00	1.1111	10.0	1.2345	1.3717	72.90
1.00	1.1111	12.5	1.2698	1.4109	70.88
1.00	1.1111	15.0	1.3072	1.4524	68.85
1.00	1.1111	17.5	1.3468	1.4964	66.83
1.00	1.1111	20.0	1.3888	1.5447	64.80
1.00	1.1111	22.5	1.4336	1.5929	62.78
1.00	1.1111	25.0	1.4815	1.6461	60.75
1.00	1.1111	27.5	1.5325	1.7028	58.73
1.00	1.1111	30.0	1.5873	1.7636	56.70
1.00	1.1111	32.5	1.6464	1.8293	54.68
1.00	1.1111	35.0	1.7094	1.8993	52.65
1.00	1.1111	37.5	1.7778	1.9753	50.63
1.00	1.1111	38.3	1.8000	2.0000	50.00
1.00	1.1111	40.0	1.8518	2.0576	48.60
1.00	1.1111	42.5	1.9323	2.1470	46 58
1.00	1.1111	45.0	2.0201	2.2446	44.55
1.00	1.1111	47.5	2.1164	2.3515	42.53
1.00	1.1111	50.0	2.2222	2.4622	40.50

F. B. BADT.

or a couple efficiency of .90 × .90 or 81%. Knowing the total power required, both electrical and mechanical, it is largely a matter of judgment as to what units this power should be divided into. This will partially be determined by the standard sizes of generators built by the manufacturer, whose

machinery it has been decided to use, as the cost of electrical machinery as well as with most classes of machines is less when regular stock or standard sizes are used, instead of having special sizes built to order.

The use of the table can best be illustrated by an example: What will be the total electrical and mechanical horse power required, and what size units should be used in a power plant to operate the following moving machinery, 5 chain coal cutters, two 50 H. P. electrical locomotives, two 25 H. P. fan motors, four 10 H. P. pump motors, with a loss of 15% in the conductors?

The total electrical horse power required by the motors is as follows:

Five coal cutters, say 20 H. P. each,	100 H. P.
Four 15 H. P. pump motors,	60 "
Two 50 " electrical locomotives,	100 "
Two 25 " fan motors,	50 "
Total electrical H. P.,	310 H. P.

By referring to column three of table we take the line in which 15, the percentage of loss in the conductor, is given, and on the same line of column four we find that 1.3072 H. P. is required in the generator for each H. P. required at the motor shaft, and for 310 H. P. at shaft, there will be required $310 \times 1.3072 = 405$ H. P. in the generators, or as generators are usually rated $\frac{405 \times 746}{1000} = 302$ Kilowatts. Now if all the machines were to be operated simultaneously, a single 300 K. W. generator would do the work, but, as the fans and pumps must never be allowed to stop on account of the safety of the miners, there would have to be an extra or reserve generator, to operate the fans and pumps in case the first generator had to be stopped for repairs. When the fans and pumps are the only machines running, a single 100 K. W. generator (which is standard size) is ample for their operation, and a second generator of the same size will operate the 5 coal cutters, and a

third is sufficient to run the two locomotives, and with the three units of 100 K. W. each, the fans, pumps and coal cutters, or fans, pumps and locomotives can be run with any two of the generators, or all three can be run together, so that for this plant three 100 K. W. generators will be the most convenient units to use. Now to determine the mechanical H P. to operate each generator, we find from the table, that for the given percentage of loss in conductors, we require 1.4524 mechanical H. P. to be delivered to the generator pulley for one electrical H. P., and for 310 H. P., we will require $310 \times 1\ 4524 =$ 450 H. P., or say three 150 H. P. engines; and, to summarize, for the most convenient operation of the plant, there will be required three 100 K. W. generators, and three 150 H. P. engines.

DETERMINATION OF SIZE OF CONDUCTOR.

Without going into the theory of electricity or its transmission, the following rules and tables will enable the size of copper conductor required to transmit a given number of electrical H. P. a given distance to be determined.

In order to apply the rules and tables the following principles relating to the generation and transmission of electricity should be understood.

The output of an electric generator or dynamo is measured in volts and amperes, the voltage being analogous to the pressure of steam in an engine cylinder, and the current to the volume of the steam. The product of the two is the work done and is measured in watts. Watts divided by 746 gives the horse power, expressed algebracially,

$$\text{H. P.} = \frac{\text{C} \times \text{E}}{746} = \frac{\text{Watts}}{746}$$

C being the number of amperes, and E the number of volts.

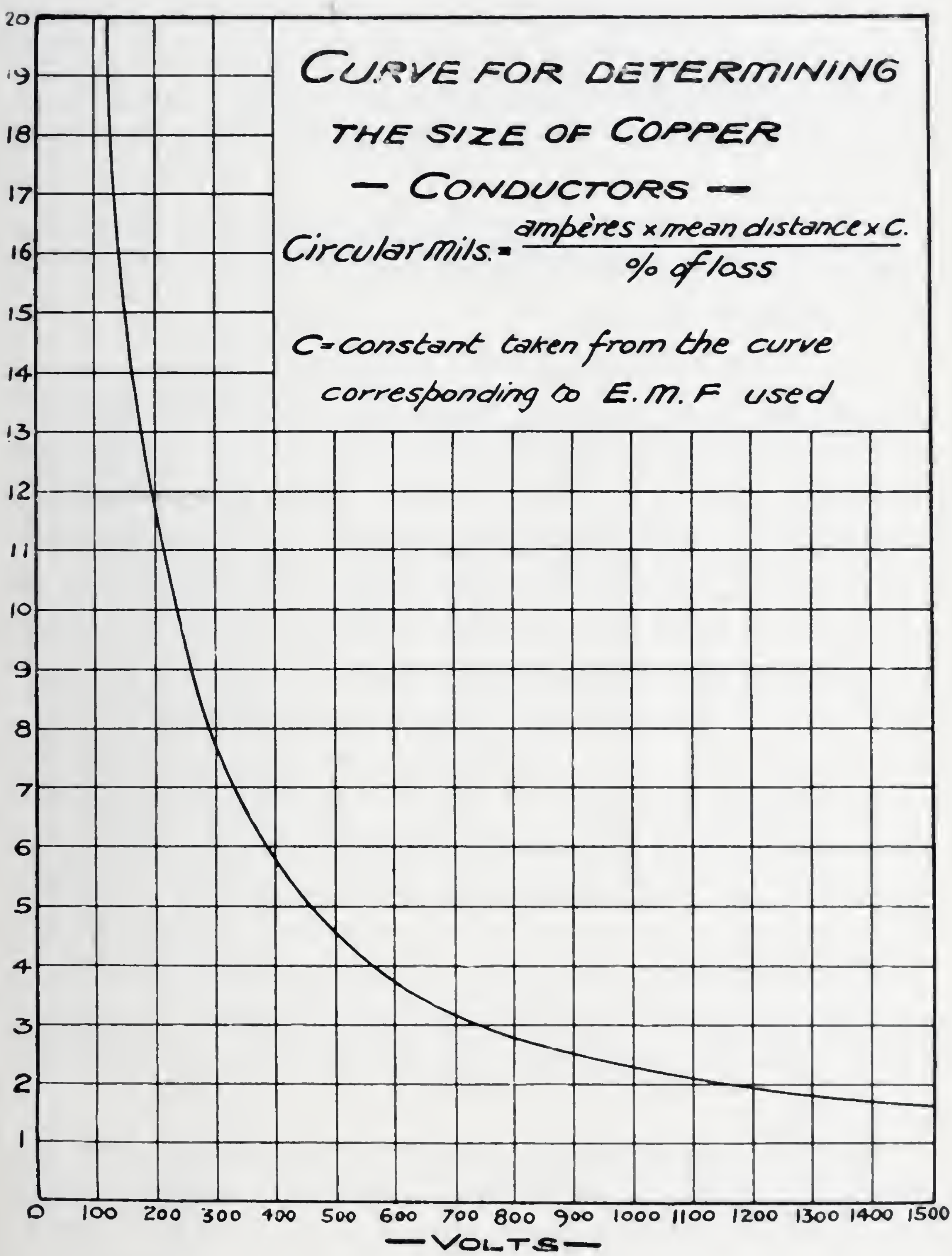
In the transmission of an electric current through a given conductor there is always a certain loss of pressure in a similar manner as the pressure of steam is reduced by friction in a pipe line; this loss is directly proportional to the length of the

conductor. The size of electric conductors is expressed in circular mills, and the size of a conductor required for transmitting a given number of amperes, depends upon the length of the conductor, the percentage of loss in voltage, and a constant which depends upon the number of volts to be transmitted.

The following formula will give the size conductor required to transmit a given current when the length of the circuit and allowable percentage of loss in pressure are given:

Circular mils in required conductor $= \frac{c \times L \times C}{N}$ in which

c=constant depending upon voltage.
L=mean distance to which current is carried.
C=amperes of current.
N=allowable percentage of loss in line.


CURVE FOR DETERMINING
THE SIZE OF COPPER
— CONDUCTORS —
Circular Mils. = amperes x mean distance x C. / % of loss
C = Constant taken from the curve
corresponding to E.M.F used
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
— VOLTS —

The diagram here given by Lemuel W. Stilwell, M. E., enables the value of *c* to be determined. By following up the vertical line corresponding to the voltage till it strikes the curve, and then taking the horizontal line passing through the same point in the curve the value of the constant is obtained. The vertical lines are drawn only for even hundred of volts, and the horizontal line for units of the constants, but decimals of both can be estimated.

The table on page 163 gives the dimensions and resistances of pure copper wire for all sizes from 0000 to 20 American gauge (Brown & Sharp).

PRACTICAL DETAILS OF ELECTRIC WIRING.

For electric locomotive trolley wires copper wires of No. 0 and 00 B. & S. gauge, weighing respectively 319 and 402 pounds per thousand feet, are commonly used. These sizes are used as with larger wires the weight is such that there would be too much sag in the line for use in low entries, without the use of a very large number of insulators. Where the length of the line is so long that with either of these sizes the loss is too great for the proper running of the locomotives, feed wires are carried along the entry a sufficient distance to reinforce the current. The return can be made by another wire, but the practice is now very general to use the rail for the return, the joints of the rails being carefully bonded; sometimes a supplementary ground wire is employed in connection with the rail.

The insulation of the wire is very important in order to prevent leakage of the current. This is accomplished by various forms of insulators which have been invented especially for mine wiring.

Where the branches lead off the main conductor to the side headings there should be placed switches, so that the current can be cut off without stopping the entire plant. There should also be placed near the same points in the branches, safety fuses, so that in case of any excessive current, the fuses will melt and prevent the burning out of the motors on

TABLE OF DIMENSIONS AND RESISTANCES OF PURE COPPER WIRE.

Am'ican Gauge B. & S., No.	Diame'r. Mils.	AREA.		WEIGHT AND LENGTH, SP. GR., 8, 9.			RESISTANCE AT 75° F.		
		Circular Mils. (d_2) 1 mil=.001 inches.	Sq. Inches. (d_2x.7854.)	Pounds per 1,000 Ft.	Pounds per Mile.	Feet per Pound.	R. Ohms per 1,000 Feet.	Feet per Ohm.	Ohms per pound.
0000	469.000	211,600.00	166,190	639.33	3,375.7	1.56	.04906	20,383	.000076736
000	409.640	167,805.00	131,790	508.01	2,677.0	1.97	.06186	16,165	.00012039
00	364.800	133,079.40	104,520	402.09	2,133.0	2.49	.07801	12,820	.00019423
0	324.950	105,592.50	82,932	319.04	1,684.5	3.13	.09831	10,409	.00030772
1	289.300	83,694.20	65,733	252.88	1,335.2	3.95	.12404	8,062.3	.00048994
2	257.630	66,373.00	52,130	200.54	1,058.8	4.99	.15640	6,393.7	.00078045
3	229.420	52,634.00	41,339	159.03	839.68	6.29	.19723	5,070.2	.0012406
4	204.310	41,742.00	32,784	126.12	665.91	7.93	.54869	4,021.0	.0019721
5	181.940	33,102.00	25,998	100.01	528.05	10.00	.31361	3,188.7	.0031361
6	162 020	26,250.50	20,617	79.32	418.81	12.61	.39546	2,528.7	.0049868
7	144.280	20,816.00	16,349	62.90	332.11	15.90	.49871	2,005.2	.0079294
8	128 490	16,509.00	12,966	49.88	263.37	20.05	.62881	1,590.3	.012608
9	114.430	13.094.00	10,284	39.56	208.88	25.28	.79281	1,261.3	.020042
10	101.890	10,381.00	8,153.2	31.37	165.63	31 38	1.	1,000.0	.031380
11	90.742	8,234.00	6,467.0	24.88	137.37	40.20	1.2607	793.18	.050682
12	80.808	6,529.90	5,128.6	19.73	104.18	50.69	1.5898	629.02	.080585
13	71.961	5,178.40	4,067.1	15.65	82.632	63.91	2.0047	498.83	.12841
14	64.084	4,106.80	3,146.9	12.41	65.525	80.59	2.5908	385.97	.20880
15	57.068	3,256.7	2,557.8	9.84	51.956	101.63	3.1150	321.02	.31658
16	50.820	2,582.9	2,028.6	7.81	41.237	128.14	4.0191	248.81	.51501
17	45.257	2,048.2	1,608.6	6.19	32.683	161.59	5.0683	197.30	.81900
18	40.303	1,624.3	1,275.7	4.91	25.925	203.76	6.3911	156.47	1.3023
19	35.390	1,252.4	983.64	3.78	20.051	264.26	8.2889	120.04	2.1904
20	31.961	1,021.5	802.28	3.09	16.315	324.00	10.163	98.401	3.2926

the mining machines or pumps. In the latest plants installed the rooms are not wired, connection being made between the machines and conductors in the entries by means of insulated wires which can be wound on reels for easy transportation from room to room. Lightning arresters should be placed in the mains at the pit mouth, and also in the power house before the mains reach the switchboard. Where the circuit is metallic, the return should also be protected.

In shaft mines the conductors are usually insulated and carried down the shaft inside of galvanized iron pipe.

Where the power is used in wet mines at a considerable distance from the pit mouth or shaft bottom, the conductors are sometimes carried over the surface on poles to a point about over the center of operation of the mining machines or pumps, and carried down bore holes, lined with wrought pipe, the conductors being insulated. Lightning arresters should be placed in both the main and return wires above the bore hole.

ELECTRIC MINING MACHINES.

The electric mining machine, while at first an experiment, has undergone many improvements in its construction, so that it may now be said to be successful mechanically, although it is still far from a perfect machine. Its use may be said to be yet in its infancy, and it more than probable that further improvements will be made which will largely increase its introduction in mines now employing hand labor exclusively, where its use is now prohibited by reason of the amount of room required by the machines in their present form. When contemplating the introduction of machine mining, there is one factor that must not be lost sight of, the cost of hand mining; and machines which would be both a mechanical and financial success in one district where the price of hand mining is comparatively high, would, while successful mechanically, prove a financial failure in another district, where hand mining is done at a much lower price than in the first district. Mr. George Gould, in a paper

read before the Western Pennsylvania Central Mining Institute, relates an instance of the kind and gives the following figures :

Machine mining :	
For cutting, which includes miner and helper, per ton	15.6c
For engineer, blacksmith, bit carrier, fuel oil, waste and wire construction, per ton	8.1c
For loading, one-half the mining rate, per ton,	25.0c
For shooting and drilling, per ton	3.0c
Total, per ton	51.7c
Pick mining, per ton	50.0c
Per ton,	1.7c

thus showing 1.7c per ton in favor of hand mining, without allowing anything for depreciation of plant or interest on cost of same, which Mr. Gould places at an additional 6 cents per ton, making a total in favor of hand mining of 7.7 cents at this particular mine. If the price of hand mining had been 70 cents a ton, as it is in some districts, the result would be a saving over the cost of hand mining, and therefore a commercial success instead of a financial failure.

Types of Mining Machines.—There are two types of electrical mining machines ; the "pick" machine and the "cutting" machine. In the former, the operation of under cutting by hand is imitated as closely as possible. The pick or bit is actuated by a heavy spring, which is compressed by means of the electric motor, the blow of the pick being given by the recoil of the spring. This type of machine has not been very successful, judging from the number of mines where it has been employed, and from the fact that the manufacturers have not pushed their introduction very energetically.

The second type are called "cutting" machines from the fact that the under cutting, instead of being done by blows

from a pick or bit, is done by revolving knives or teeth. There are two classes of this type, the "bar" and the "chain" machine. In the former, the teeth are placed on a horizontal bar, which is revolved by means of an endless chain, and they revolve in a vertical plane, while in the latter, the teeth are set in an endless chain, which revolves in a horizontal plane, the action of the knives or teeth being at right angles with those of the bar type. Figures 7 and 8 show the general appearance of the "chain" machine.

Advantages and Disadvantages of the Different Types.— The advantage of the "pick" machines, if they were mechanically perfect, would be in the less first cost; that they can be worked in any place where a miner could work with his hand pick, and that their comparatively small size and weight makes them easily handled and taken from room to room by one man. The disadvantage is that the success of the machine and the amount of under cutting done by it, depends entirely upon the manipulation of the operator handling it

One great advantage of the "cutting" machine is, that when it is set up and the current turned on, the operation is entirely independent of the operator, and that all he has to do is to watch it, and when the cut is made, withdraw the cutting chain from the cut, move the machine over, set and start it on its next cut. The disadvantage of the machine as now made, is the amount of clear space required between the face of the coal and the props or "gob," at least twelve feet, and in some machines fifteen feet being required. This space, with a bad roof, is difficult to obtain on account of the posts required to support the roof; the firmness required by the machine is also a difficult thing to obtain with a bad roof, as the rear brace of the machine requires a good, solid hold in the roof. However, where the physical conditions of the mine are such as to allow its use, there can be no doubt of the success of the "cutting" machine.

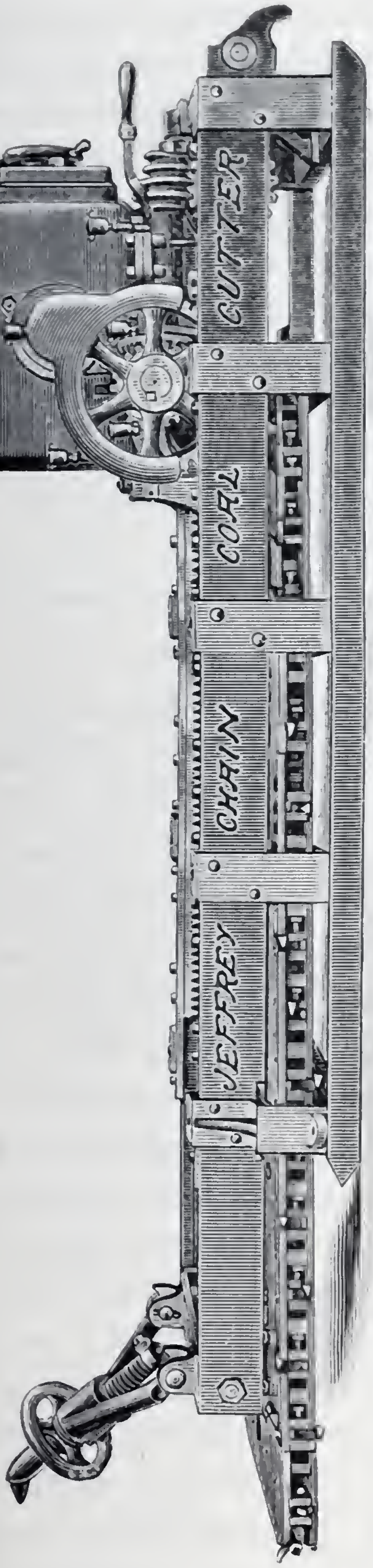


Fig. 7. Jeffrey Chain Coal Cutter.

Fig. 8. "Independent" Chain Coal Cutter.

Construction.—In the construction of "cutting" machines there are five principal parts, viz: the frame which forms the support of the working parts; the sliding frame carrying the the cutter chain; the cutter chain; the motor and the device for feeding and withdrawing the chain frame. These parts are common to the various makes, and they vary only in the details. In the Jeffrey machine, the supporting frame is entirely outside of the travelling frames, while in the "Independent," the travelling frame is on top of the supporting frame. In the Jeffrey machine, the feed mechanism consists of pinion and rack movement, while in the "Independent" the feed and return are accomplished by means of sprocket wheels and chains, that for the return being much faster than the feed. There are many other details in which the machines differ, but those mentioned are two of the most important differences.

Capacity of Electric Mining Machines.—The capacity of mining machines in different mines will vary, according to whether the conditions are favorable to their being worked to their full limit. It will depend somewhat upon the thickness of the vein, as the depth of the undercutting is generally equal to the thickness of the coal, and also because in thick veins it is easier to move the machines from cut to cut and room to room, than in thin veins where the headroom is so low that the men cannot stand or work upright. It will also depend upon what kind of material the undercut is in, whether in clay or coal, and also upon the system of mining, whether pillar and room or long wall, the latter system not requiring the machines to be moved on the trucks so frequently as the former. The capacities of the various machines is frequently stated in tons per day of output, but as the thickness of the coal varies so much in different mines and districts, that for the purposes of comparison it is better to state the capacity in square feet of undercutting per shift of ten hours, which will cover not only the actual time the machine is at work, but will also include the time occupied in moving, set-

ting up, and setting teeth; the thickness and nature of the coal should also be given. Data of this kind that has found its way into print is quite meagre, but the following figures, kindly furnished by operators, will serve to give an idea of what the various machines are capable of doing under various conditions.

Mr. Geo. Gould reports that three machines of General Electric type, working in a three-foot vein where the under-cutting is done in a band or clod about two inches thick and very hard, each machine cuts on an average of four rooms per day, or 96 lineal feet of face, which for a cut 5 feet deep would make 490 square feet.

In a mine in the Panhandle district of Pennsylvania the "Independent" make of machines cuts on an average of 70 lineal feet per day, or 350 square feet. The cutting in this mine is very hard, as many as three sets of teeth being used in a single cut, which of course, makes the time of making a cut much longer than if no teeth had to be replaced during a cut.

In a Kentucky mine with vein 4 feet 8 inches to 5 feet thick, known as the Kentucky No. 9, the coal having considerable sulphur in it, the "Independent" machine averaged for the month of January, 1897, 125.8 feet of face, cutting five feet under, or 629.0 square feet per shift.

Power Required to Operate Electric Mining Machines.— Up to a recent date no extensive and systematic experiments seem to have been made to determine the exact amount of power required in the operation of electric mining machines. Some of the manufacturers of mining machines may have made such experiments, but if they have, none of the results have found their way into print. Believing that such data would be acceptable to mining engineers and mine operators, Mr. Robert M. Haseltine, the Chief Mine Inspector of Ohio, made a series of tests with twelve mining machines, in seven different mines in that State. In these tests the circuit was opened near the machine and meters registering potential and

current were inserted. Simultaneous readings were taken every fifteen seconds while seventy-three cuts were being made. In all, over 1,400 readings were made, which were taken and reduced with the utmost possible precision.

The results of the experiments showed that the average maximum electrical H. P. used in cutting, ranged from 9.8 to 22 for the chain type and for the cutter bar type from 18.5 to 26.9. To quote Mr. Haseltine: "These results are of the highest importance to those contemplating the installing of mining machines. They should use the highest power exhibited under the type of machine selected as to the multiple by which to determine the power of the generator necessary to insure satisfactory results." In view of these figures it would seem that the generator should be of ample power to generate at least 25 electrical H. P. for each bar coal cutter and 20 H. P. for each chain machine to be employed, with ample allowance for loss in the conductors and for possible additions to the number of mining machines. The four experiments made with the Jeffrey electric drill showed that its operation required as a maximum $3\frac{2}{10}$ electrical H. P.

ELECTRIC HAULAGE.

The first electric mine haulage plant was installed at the Erie Colliery near Scranton, Pa., in 1889. Since that time, so many improvements have been made in the construction of electric mine locomotives, that its success, both mechanical and commercial, can no longer be considered doubtful in mines where its use is not prohibited by excessive grades or explosive gases.

It is generally admitted by both electrical engineers and manufacturers that where grades exceed 3%, some form of rope haulage will be more economical in its operation; and where the grades are not prohibitory, but where gases make the use of electricity dangerous, and will probably be preferred to rope haulage.

The application of electricity to mine haulage can no

longer be considered in an experimental stage, as the writer has reports from a large number of mines where it is in use, and they all report that the mechanical results are perfectly satisfactory, and that the saving over mule haulage is from three to eight cents per ton of output.

The electric locomotive as now made is a very compact machine, and takes up so little head room than in thin vein mines there is a large saving in not being compelled to take up as much bottom, if any, as has to be done to give head room for the mules where they are used to haul the mine cars.

The principal makers of the electric mining locomotives are the General Electric Company, the Jeffrey Manufacturing Company, of Columbus, Ohio, and the Link Belt Machinery Company, of Chicago. The general appearance of the locomotives made by the first two makers is somewhat similar. Both have heavy cast iron frames with inside wheels, the motors being entirely concealed. Both have two motors: one for each pair of wheels and are single reduction, that is, the toothed pinion of the motor engages a toothed wheel on the wheel axles of the locomotive. The principal difference in appearance between the two machines is that, in that of the General Electric Company, the motorman sits at one end only, while in the Jeffrey (See Fig. 9) machine, he sits in the middle, the two ends of the machine being exactly alike. The standard sizes of the General Electric Company are 50, 80 and 160 horse power, weighing from 4,400 lbs. to 20,000 lbs., while the principal sizes of the Jeffrey Company are 40, 60 and 80 horse power.

The "Independent" locomotive of the Link Belt Machinery Company (See Figs. 10 and 11) differs radically in appearance and construction from those of the others mentioned. Instead of being a two-motor machine, it is operatedby a single double-reduction bi-polar motor, geared to both axles, thus assuring both axles revolving at the same speed. The wheels

Fig. 9. Jeffrey Locomotive.

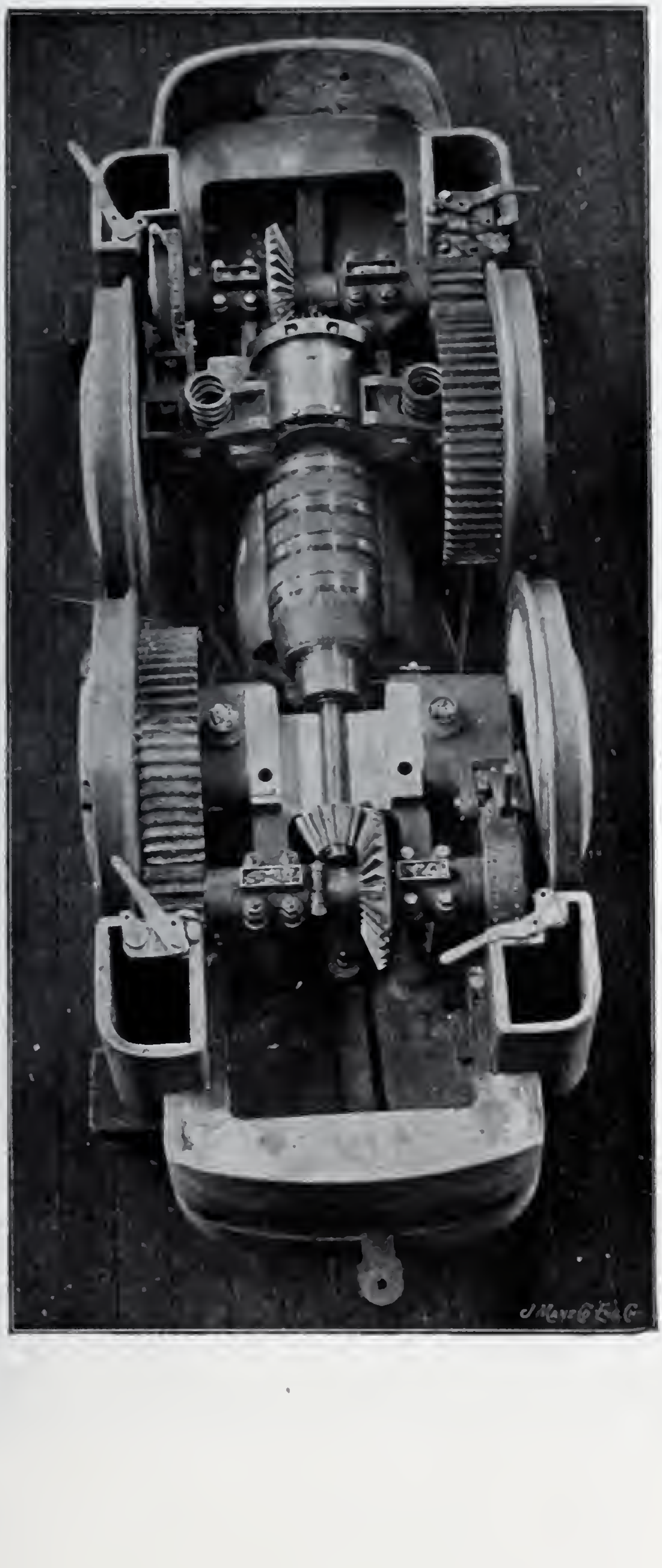


Fig. 10. "Independent" Locomotive (top view).

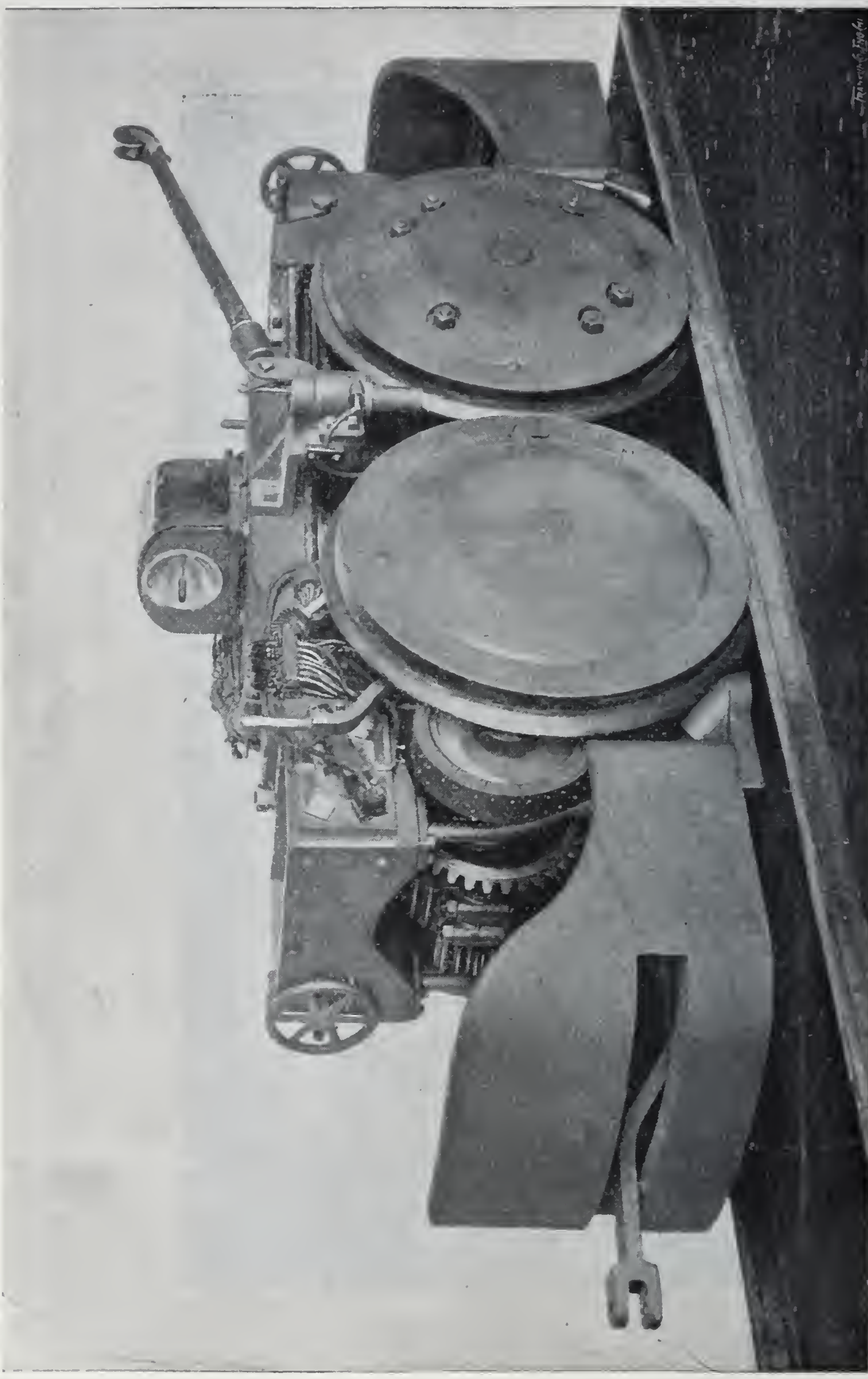


Fig. 11. "Independent" Locomotive (side view).

are 36 inches in diameter, which is conisderably larger than those in the other two, and the entire mechanism and frames are inside the wheels.

ELECTRIC MINE PUMPS.

In mines employing electrically operated mining machines or locomotives, the same power may be advantageously employed for operating pumps. It may also prove economical to install a small generating plant in mines where its use would not be general, for the purpose of operating pumps situated at a considerable distance from the pit mouth or shaft bottom. The use of electric pumps in remote parts of the mine, where it would be necessary to employ a man to watch steam or air driven pumps, is economical, as with shunt wound motors, receiving a current of uniform voltage, they will maintain a constant rate of speed under varying loads and will regulate automatically. This makes them peculiarly adapted to mine work, as with steam or air driven pumps, should the sump be pumped dry and the pumps draw only air, they would run away with themselves, unless closely watched and the power shut off until the sump had filled up sufficiently to enable them to be started again. With electrically driven pumps, this can not happen, as they will run at the same speed whether pumping air or water, and will not, therefore, require the constant attention of a man to prevent accidents from racing.

Electric driven pumps are now made that give very good efficiencies. At a mine of the Colorado Fuel & Iron Company, the following results were obtained:

The average results of two small electric 7″ x 10″ pumps were as follows:

Average gallons per minute discharged	500
Average pressure at pumps	56.5 lbs.
Average strokes per minute, each pump	172
Average amperes	37
Average station voltage	475
Average I. H. P. at engine	32.86
Average H. P. at pump discharge	16.4

Efficiencies,

Generator unit, engine and dynamoes	71.5%
Motor, pump and line	70.0%
Total from engine cylinder to discharge of pump	50.0%

From a 9.5 x 12 inch pump, the following results were obtained :

Average gallons per minute discharged	650
Average pressure at pump	64 lbs.
Average strokes per minute	188
Average amperes	53.5
Average station voltage	550
Average I. H. P. at engine	53.6
Average H. P. at pump discharge	24

Efficiencies,

Generator units	73.0%
Motor, pump and line	61.0%
Total from engine cylinder to pump discharge	44.5%

These tests were all made with engine and dynamo working at only 20% of their full load, and Mr. Lewis Searing, the engineer who installed the plant, predicts an efficiency of at least 60% when working at full load.

A rough test of a plant at the Maltby mine of the Lehigh Valley Coal Co., with an electrically driven pump with 10″x18″ cylinders against a head of 360 feet, gave a total efficiency of 52.9%, the pumps being over a mile from the power house. These efficiencies as compared with some of the steam or air pumps now in use at long distances from the power house, are comparatively high.

There are two classes of electrically driven mine pumps, portable and stationery The former are generally mounted on trucks so that they can be easily transported; they are of either the triplex power type or centrifugal; while the stationary pumps are usually of the triplex type for the smaller sizes, and the horizontal double acting cylinder type for the larger sizes.

For pumping out dip headings, the portable pump is very useful; as the heading is extended, the pump is simply dropped down on the trucks, and the pipe and wire connections are easily and quickly made.

One objection to the use of electric motors for driving large horizontal pumps, is that the speed of the pump is comparatively slow and in a straight line of motion, while the speed of the motor is much greater and rotary in direction, and the combination requires the introduction of gearing for the purpose of speed reduction, and changing the rotary motion of the motor to the straight line motion of the pump piston. This gearing, of course, introduces a large element of friction, but it is claimed by advocates of electricity that this objection is more than overcome by smoothness of running, and the fact that when once started, it requires no attention other than keeping the working parts well oiled.

ELECTRIC HOISTING ENGINES.

Electric hoisting engines, so far as the author can ascertain, have not been used as yet for the main hoisting engines for a shaft, or for the main haulage of drift or slope mines in the bituminous coal districts. Those in use up to the present have been confined to what may be termed secondary haulage, that is for hauling cars out of dip headings at some distance from the pit mouth, where the grades are too steep for a locomotive, to the main haulage ways where the trips are made up. Their application to this purpose, where the distance from the boiler plant is too great for the use of steam hoisting engines, would seem to be an admirable one, and in plants where electricity is already in use for mining machines and electric locomotives, it is probably as cheap a method as could be adopted.

The uses of electricity mentioned above are the principal ones to which it is put in mine work, but there are other minor applications to which electric motors can be applied, such as operating ventilating fans, revolving or shaking screens, and

slack conveyors. These latter applications should not be made indiscriminately simply because the main operations of the mine are carried on by this medium. When these machines are being operated at a time when coal cutting is not going on, it may mean that one of the generators must be run, simply to furnish a small amount of power very much less than its rated capacity. For this reason the author believes that it may be cheaper and better to use small stationary engines for some purposes, rather than electricity, even though the mine is equipped with an electric power plant.

THE PRESIDENT—You have all heard this interesting paper; has any one anything to say? Mr. Shellenberg, have you anything to say?

MR. SHELLENBERG—Nothing.

THE PRESIDENT—Mr. Taylor?

MR. TAYLOR—It is too late to take up such an important subject.

The question here arose as to whether or not the Society should take up the discussion of the new constitution postponed from last meeting, or discuss the papers. It was stated that there were so many topics open for discussion at present, with the likelihood of there being several others of kindred nature in the near future, that if they were being continued and put off from time to time they would never be discussed, therefore it was finally decided to hold semi-monthly meetings until these topics could be disposed of. Adjourned.

REGINALD A. FESSENDEN,
Secretary.

MEETING OF THE CHEMICAL SECTION.

PITTSBURG, MARCH 18th, 1897.

The regular monthly meeting of the Chemical Section was held in the rooms of the Society, March 18th, 1897. Chairman, W. E. Garrigues; attendance, 14. The minutes of the last regular meeting were read and approved.

Mr. J. O. Handy, for the Committee on Chemical Literature, made a very complete report on recent Chemical Literature.

The Chairman appointed the following committee to investigate the French method of making carbon determinations, described by Blair in the Journal of the American Chemical Society: J. M. Camp, Geo. O. Loeffler, J. S. Unger.

On motion of J. M. Camp, it was unanimously resolved to direct the Secretary of the Section to communicate to the Secretary of the Engineers' Society, the wish of the Section to have representation on the Board of Directors, in the person of its Chairman, and to ask that some action leading thereto be taken by the Society in connection with the adoption of the new constitution.

Mr. J. O. Handy made some remarks in conclusion of his article on "Filtration," which were discussed by Messrs. Garrigues, Stahl and others.

Mr. A. G. McKenna read a paper on the Analysis of Chrome Ore, which was discussed by Messrs. Camp, Handy and others.

The Section adjourned at 11 P. M.

A. G. McKENNA,
Secretary C. S.

THE COMPLETE ANALYSIS OF CHROME ORE.

A serious objection to most methods of chrome ore analysis has been the difficulty of obtaining complete decomposition of the ore without prolonged and repeated fusions with the reagents generally employed for that purpose.

By fusing the ore with sodium peroxide, which is now coming into general use as an analytical reagent, any chrome ore is completely decomposed in a few minutes. The fusion should not be made in platinum as the peroxide attacks the crucible strongly. A nickel crucible is best to use, although it is also attacked and cannot be used more than twenty or thirty times. On leaching out the fusion with water all the chromium goes into solution as sodium chromate, the oxides of iron, nickel and magnesium remain in the undissolved residue. The following method for the determination of silica, oxide of iron and chromium, alumina lime and magnesia is based on the above mentioned facts.

FOR THE DETERMINATION OF OXIDES OF IRON AND CHROMIUM.

One half gram of the fine ground sample which has been dried at 100° C. for one hour is weighed into a nickel crucible of about 20 cc. capacity, in which has been placed three or four grams of sodium peroxide; after thoroughly mixing the contents the crucible is held over a Bunsen burner by means of a pair of suitably shaped tongs, until fusion begins. The mass is kept in a liquid condition at a low red heat for about one minute, which is sufficient to ensure complete decomposition if the ore is at all finely ground. After allowing the crucible to cool it is placed in a 400 cc. beaker with a watch glass cover and hot water added until the crucible is covered.

The beaker is placed on a hot plate for a few minutes until the fusion is dissolved; the crucible is then removed by means of a glass rod and the contents of the beaker allowed to settle for a few minutes. When the insoluble matter has subsided it is collected on a 9 c. m. filter paper, the filtrate being re-

ceived in a 500 cc. flask. The residue on the paper which contains all the iron is ignited in a platinum crucible, fused with two or three grams of potassium bisulphate, dissolved in dilute sulphuric acid (1:10), reduced by filtration through amalgamated zinc, and titrated in the usual manner with standard permanganate. The result is calculated to ferrous oxide.

The filtrate in the 500 cc. flask, which contains all the chromium as sodium chromate in an alkaline solution is boiled for about ten minutes in order to ensure the removal of all peroxide which, if allowed to remain until the solution is acidified, would react on the chromate, reducing it to the sesquioxide.

When the removal of the peroxide is complete the solution is allowed to cool and then acidified with a large excess of dilute sulphuric acid (1.4).

The solution is transferred to a 1,000 cc. beaker, and diluted to about 800 cc. with cold water. To this solution 70 cc. of a ferrous sulphate solution, containing 10 grams of Fe in the ferrous condition to the liter is added, this is sufficient to reduce the chromic acid corresponding to .3167 grams of chromic sesquioxide. The excess of ferrous sulphate which has been added is determined by back titration with standard permanganate solution, of which 1 cc. is equivalent to 1 cc. of the ferrous sulphate solution. Such a permanganate contains 5.643 grams $KMnO_4$ to the liter. The difference between the cubic centimeters ferrous sulphate used and cubic centimeters of permanganate used, multiplied by .905, gives percentage of chromic sesquioxide in the ore.

For the determination of SiO_2 (Al_2O_3, Fe_2O_3, Cr_2O_3) $CaO+MgO$ fuse one-half gram of ore in nickel crucible as before, dissolve in about 50 cc. hot water in a covered 5″ porcelain dish, remove crucible and acidify with hydrochloric acid, evaporate to dryness, take up in dilute hydrochloric (1.4) filter, ignite and weigh as SiO_2. To the filtrate add 10 cc. strong hydrochloric acid make ammoniacal, pass hydrogen

sulphide, allow to settle, filter off the precipitated hydrates of ichromium and aluminum and the sulphides of iron and nickel, dissolve the iron chromium aluminum in the dilute hydrochloric and reprecipitate as before with hydrogen sulphide, filter, and in the combined filtrates determine lime and magnesia in the usual manner.

Redissolve the iron chromium and aluminum precipitates from the filter paper with dilute hydrochloric acid, oxidize with a few drops of nitric acid, precipitate with ammonia, filter, wash free from ch!orine, ignite and weigh as Al_2O_3, Cr_2O_3, Fe_2O_3, from this weight subtract the $Cr_2O_3 + Fe_2O_3$, calculated from the percentage of iron and chrominum found in previous analysis, which will give the Al_2O_3.

TRANSMISSION OF POWER BY COMPRESSED AIR.

BY RICHARD HIRSCH.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA, PITTSBURG, PENN'A.

In papers presented to this Society at different times, various methods of transmitting power in the city of Pittsburg have been advocated. Up to the present time, however, the only agent which has been utilized for this purpose is electricity, unless we mention our city water supply, which has been used for hydraulic elevators, and in a few instances for motors operating light machinery.

It has been unfortunate for the reputation of compressed air, that so little attention has been given to its development as an efficient transmitter of power. In most applications, its peculiar advantages, such as safety, non-condensation during transmission, and unobjectionable exhaust, have been features of first consideration. Little attention was given to economical operation, inefficient compressors and wasteful motors being used. Compressed air has many advantages which entitle it to a more general recognition as an efficient means of transmitting and distributing power in cities.

In the use of steam, the loss by condensation in the pipe lines, the necessity for expensive pipe coverings and expansion joints, and the objectionable exhaust, either as steam or hot water, are disadvantages not met with in the use of compressed air. The high cost of hydraulic power, and the limited possible applications of the same, place it in an unfavorable light, when brought into competition with pneumatic transmission. The ease with which electric wires can be strung on poles, over housetops, and through buildings, and the low cost of such work, have been great factors in the rapid increase in the use of electrical machinery, much more so, in fact, than the cost of electric power. But vigorous

protest should be made against the disfiguring of house fronts and interiors, by the promiscuous array of wires, insulators and transformers. The conversion of our streets into veritable forests of unsightly poles, carrying net works of highly charged and uncovered wires should not be tolerated. When electric conductors are laid underground, and interior wiring concealed in the walls and floors of buildings and securely insulated, the cost of such work equals, if not exceeds, the cost of piping required for transmitting power by other agencies.

Compressed air is used at pressures varying from that of a more or less perfect vacuum up to 5,000 lbs. per square inch. There is a power transmission system in Paris where motors are operated by the pressure of the atmosphere and exhaust into mains in the streets, in which a more or less perfect vacuum is maintained by air pumps situated at a central station. Pressures of from 60 lbs. per square inch to 90 lbs. per square inch are used for ordinary power purposes; from 400 lbs. per square inch to 800 lbs. per square inch for pneumatic locomotives; 2,000 lbs. per square inch for street cars, and from 1,000 lbs. per square inch to 5,000 lbs. per square inch for pneumatic dynamite guns and other purposes on war vessels.

The gratifying results obtained in the use of compressed air for operating locomotives and shop machinery, and the high efficiency that could be obtained in a properly designed plant for the general transmission of power, lead the author of this paper to believe that such a plant could be successfully operated in the City of Pittsburg, considered both from an engineering and business point of view. The following is a description of a proposed plant capable of transmitting 1,100 indicated horse power, developed in the motors where used, with the cost of building and operating the same.

In a fire proof building situated on the banks of one of our rivers, and as near the business portion of the city as possible, will be installed the necessary boilers and air compressors. Water for feeding boilers and cooling purposes will be pumped

from the river, thereby saving water tax. Coal will be received by rail or boat, and handled by machinery. Ashes will also be handled by machinery, and loaded into boats or cars as required. Boilers will be of the water tube type, fitted with mechanical stokers, and capable of developing 2,000 indicated horse-power in the steam cylinders of the compressors. There will be two air compressors, with triple expansion condensing engines of the Corliss type, having steam cylinders 20″, 34″ and 50″ diameter, by 42″ stroke. The air cylinders will be compound, two for low pressure, each 26″ diameter, and one for high pressure, 30″ diameter; all 42″ stroke. The air will be taken at atmospheric presssure through a cooling apparatus, and specially adapted Corliss valves into the two low pressure cylinders, and discharged through an inter-cooler, into the one high pressure cylinder ; the air will there be compressed to 100 lbs. per square inch, and delivered through a cooler into the pipe line. Each compressor will be capable of delivering about 6,000 cu. ft. of free air per minute, compressed to 100 lbs. per square inch gauge pressure. The compressor will be fitted with automatic valves which will reduce their speed when the pressure in the pipe line runs up to a little more than 100 lbs. per square inch and speed them up again when the pressure falls. It might, however, be advisable to subdivide the compressing machinery into three or more units to facilitate repairing and lessen the liability of seriously crippling the plant in case of accident, or break-down. The two larger units as here described are from an estimate kindly furnished for this paper by the Norwalk Iron Works Co. There is no necessity for large storage tanks or reservoirs, as the air mains provide sufficient capacity to permit the air to be pumped directly into them. Moisture will be withdrawn from the mains by suitably arranged traps and delivered into the sewers. These traps need be but comparativly small affairs, connected to the air mains by pipes of small diameter, and enclosed in the street boxes with the shut-off valves. For

the reason that watery or other vapors can not be compressed to a density greater than that due to their temperature, the watery vapor in the air would condense soon after compression and most of it would be drawn off near the power house.

The main pipe line from the power house will consist of 12″ wrought iron pipe coupled together by bolted flanges. It will extend to where the next work of street distributing mains begins, and will there be reduced in size as the carrying capacity and frictional resistance of each branch of pipe permits. The street distributing mains will consist of 6″ and 8″ wrought iron pipe coupled together by threaded sockets. No expansion joints will be required, as the mains being laid below the frost line, and the air being cooled after compression in the power house, there will be no more variation in the temperature of the air mains than there is in water or gas mains, neither of which are provided with expansion joints. The expansion joints on the underground steam lines of the New York Steam Heating Co. are quite elaborate and very expansive affairs, and are placed at close intervals. In connection with pneumatic locomotives, wrought iron mains with screwed sockets and without expansion joints are used, carrying pressures of from 400 lbs. per square inch to 700 lbs. per square inch. The satisfactory results obtained in the use of these lines furnish a precedent for advocating street distributing mains of practically the same description, although various other kinds of joints have been used in Paris and elsewhere for this purpose.

In the Paris system, steel mains 20 inches in diameter are used, having perfectly plain ends and connected together by the so-called Normandy joint, which is described in Unwin's Development and Transmission of Power. It consists of two bolted cast iron flanges, each having an annular recess containing an india rubber ring. When the flanges are drawn together, a metal gland or thimble tightens the rubber ring against the pipe, thus forming, as it were, a double stuffing

box at each joint. It permits expansion and contraction, and the leakage is said to be negligible. It is not unreasonable to suppose that in time, the rubber will get hard or brittle or possibly will rot from contact with moisture. If there is movement of the several parts at each joint due to expansion and contraction the consequent wear will eventually cause leakage, and the joints being inaccessible, will be costly to repair. The joints should certainly be as permanent as the pipe line itself, and any necessary allowance for contraction or expansion should be made where easily accessible for repairs, as in the street boxes which inclose the stop valves. Prof. Unwin states that in cast and wrought iron mains with lead joints, there is considerable leakage, and in Birmingham the leakage with this kind of joint amounted to 45% of the whole air supply.

In estimating the cost of construction it has been assumed that the power station could be located within 8,000 feet of Eleventh or Grant streets, and allowance has been made for that length of 12 inch main. Provision has been made for laying pipes on all the principal streets of Pittsburg, situated between the Monongahela and Allegheny rivers and on and below Grant and Eleventh streets. Stop valves inclosed in suitable street boxes will be provided at frequent intervals in the mains, by means of which the air supply can be shut off from any section of pipe undergoing repairs, or while service connections are being made. At such times the air can be made to pass the portion of the main thus cut out, through the pipes in the adjoining streets, causing inconvenience to but few users of the power. Much annoyance could be averted by making service connections at night, or if made by day, appliances could be used which permit making connections to pipe lines without shutting off the supply. The estimate does not cover the cost of service connections, as they will be paid for by the consumers of the power, but does cover the cost of meters. Liberal margin has been allowed in the various items, and the

following figures would undoubtedly cover the actual cost of construction. Allowance has been made for dividing the boilers and compressors into such units as to provide reserve power, available in case of accident or while repairs are being made.

COST OF CONSTRUCTION.

Real Estate	$ 30,000 00
Buildings	20,000 00
Compressors erected on foundations with Condensers and attachments	55,000 00
Boilers	21,000 00
Stack and Britchen	3,750 00
Mechanical Stokers	4,375 00
Circulating and Feed Pumps, Injectors, etc	4,000 00
Cooling Apparatus	2,000 00
Water Tanks	1,500 00
Coal and Ash Conveyors	4,000 00
Pipe Lines and Distributing Mains	70,000 00
Meters	5,000 00
Engineering and Expenses of Organization	25,000 00
Miscellaneous Items, including electric light plant and crane for power station	10,000 00
Contingencies	19,375 00
Total cost of plant	$275,000 00

COST OF OPERATION PER ANNUM.

Interest on investment of $275,000.00 @ 6 per cent	$ 16,500 00
Deterioration 4 per cent. of $275,000.00	11,000 00
Taxes	3,500 00
Fuel	5,000 00
Salaries and Wages	16,500 00
Repairs and Supplies	5,000 00
Office Expenses	2,500 00
Total annual cost of operation	$ 60,000 00

It is estimated that the plant will deliver 1,100 H. P. for 3,000 hours and 200 H. P. for 5,760 hours per annum, or a total of 4,452,000 H. P. hours per annum. The annual cost of operation, divided by 4,452,000 gives 1.35 cents per H. P. per hour, or $40.50 per H. P. per annum of 3,000 hours. The cost of power to consumers would be graded somewhat, according to the amount used. This would not be a hardship

to small users of power, because to such consumers the power would be cheap at any reasonable price. To users of power in moderate quantities, the cost per H. P. per annum, including attendance, cost of heating and interest on cost of motors and heaters would not be more than $50.00.

For deterioration, there will be laid aside each year out of the earnings, 4% of the total investment, and this money placed at 3% compound interest will, in about 19 years, equal the capital invested or sufficient to rebuild the plant entire. It will be noted that the cost of operation would increase but slightly with considerable increase in the capacity of the plant, and also that the cost of construction would not increase in direct proportion to such enlargement of the plant. If the building of a larger plant would be justified, the cost of power to consumers would be less than given.

To compare the cost at which power could be furnished by compressed air with the cost as furnished by other means, I extract the following from our proceedings, being estimates given in papers read by members of this society at different times.

Amount per H. P. per annum paid to the City of Pittsburg for operating hydraulic elevators, (about)	$700.00
Cost of power per H. P. per annum in a large store having its own plant, 15 hour service	128.44
Cost in same plant corrected for 10 hour service	89.92
Estimated cost per H. P. per annum at which power could be furnished by a proposed hydraulic power company, with no allowance made in operating expenses, for taxes or deterioration of plant	77.70
Cost in same plant corrected for above omissions	100.20
Estimated cost per H. P. per annum at which power could be furnished by an electric power company capable of delivering 20,000 H. P.	50.00

The low cost at which power can be furnished by compressed air can only be approached by electricity working under the most favorable conditions. The rates paid for power to the electric companies in Pittsburg at the present time are excessive.

EFFICIENCY OF THE SYSTEM.

It can be shown theoretically and has been proven in practice, that one cubic foot of free air, when compressed to about 90 pounds per sq. in., is capable of performing from 2,600 foot pounds to 3,000 foot pounds of work, when used cold. From actual tests it has been found that by heating the air, this can be increased 40%. Prof. Unwin states that the experiments of Riddler and Gutermuth show that heat thus applied is used five or six times more efficiently than if used in a good steam engine. The compressors, as above specified have a combined capacity of 12,000 cu. ft. of free air per minute. Deducting 15% of this for loss by leakage and friction in pipes we have 10,200 cu. ft. of free air available for useful work; or expressing it in foot pounds per minute, we have $10,200 \times 2,600 \times 1.4 = 37,128,000$, or in horse power, we have $37,128,000 \div 33,000 = 1,125$ H. P. which is 56% of the indicated H. P. in the steam cylinders of the compressors; assuming the efficiency of the motors where the power is used to be 90%, we have an efficiency of over 50% in the entire system, from the indicated horse power in the steam cylinders to the brake horse power in the motors. This compares favorably with electric transmission, which under average conditions is about 58%. Much higher efficiencies than 50% have been given by writers on this subject, but the figures here given are based on the actual capacity of the compressors after due allowance has been made for internal friction and other unavoidable losses, such as leaking stuffing boxes, valves and pistons; and more especially the loss occasioned by the heating of the air during compression. Moreover, the builders of the compressors will guarantee the capacity as here given,

and the estimates from two different firms showed practically the same indicated horse power in the steam cylinders of the compressors to produce the amount of air required.

One thing to be noted in the use of compressed air, is the fact that the loss caused by the fall in pressure resulting from friction in the mains, is partly made up by the increase in volume. In a hydraulic system a fall in pressure, caused by friction in the mains, results in a loss in direct proportion to the fall in pressure; the volume remains the same. The efficiency of the system can be considerably increased by using compound motors, in which the air would be heated before entering the motor and reheated between the first and second expansions; the motor being somewhat similar to a compound steam engine with a receiver between the high and low pressure cylinders, the receiver in this case being a reheater. When the air is heated to increase the economy, the most efficient results are obtained when moisture is added, which by giving out its latent heat in the motor, materially increases the efficiency. For this reason heaters are generally of the hot water style, wherein the air passes through hot water under pressure, and part of it goes to the cylinder of the motor in the form of steam.

USES OF COMPRESSED AIR.

Compressed air can be applied to such a wonderful variety of uses that a ready market for the entire power of the plant is almost assured, and the project would undoubtedly be as profitable in a financial way as it has been elsewhere, notably in Paris. The power would be used for the operation of elevators, electric light plants, ventilating apparatus, pneumatic tools, and motors. It would also be used for parcel and cash conveyors, cleaning and cooling purposes; for the latter purpose either air direct from the mains, or exhaust air from the motors would be used. For comparatively small addition to the cost of building the plant, a system of regulating clocks could be installed, and but very little power would be required to operate it. Some of the new office buildings in the East have

been piped for delivering compressed air to the tenants, the same as they would be provided with hot and cold water. Compressed air only lacks the capacity to supply heat, to enable it to operate the entire mechanical plant of the modern office building. Heat would be supplied by the boilers in the building but not being called upon for lighting or power purposes, would be operated only during the cold months of the year. In the ideal plant, however, heat would be furnished by the hot water system, and power and light by air, the cost of operation being thereby reduced to the minimum.

The project could be still further enlarged upon. While laying the distributing mains ducts could be laid for a parcel delivery system. Stations would be located in different portions of the city, where parcels would be received, and sent through the chutes to the station nearest to the destination of the package, and the delivery be completed by messenger.

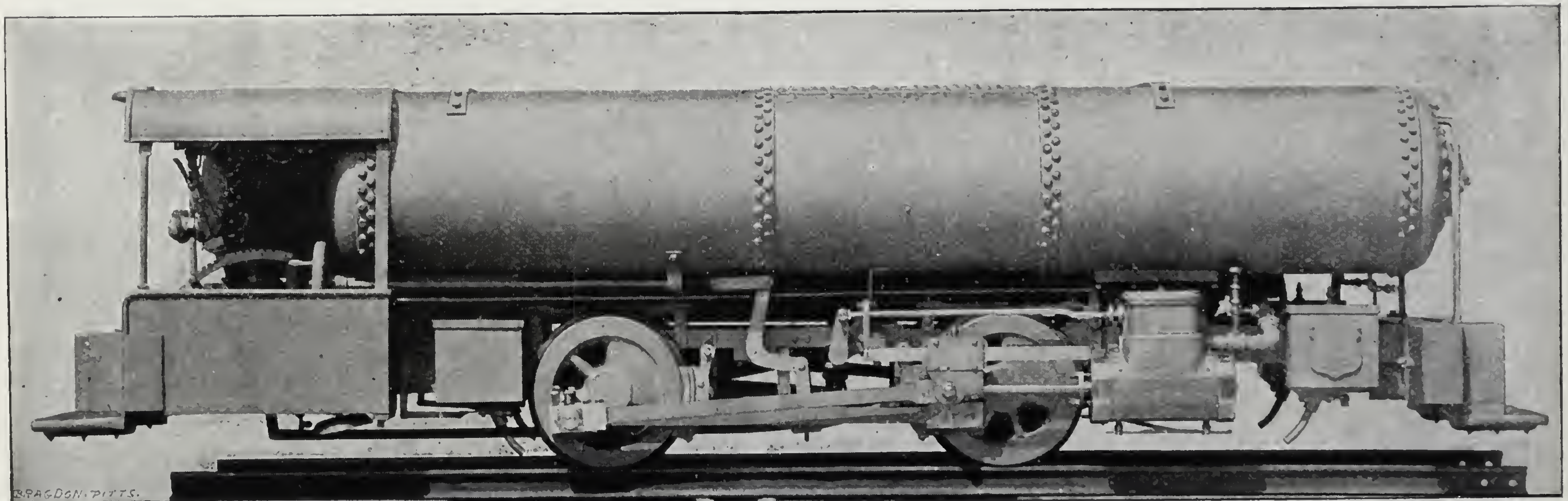
It would be practicable to have street connections in close proximity to the fire plugs, and operate fire engines by air, which could then be built much cheaper, lighter in weight, less complicated in detail, and would be ready for immediate service at all times. In fact, the practicable applications of the power are almost unlimited and the project would certainly meet with success, and pay handsomely on the capital invested. It would increase our business and manufacturing facilities and assist greatly in making Pittsburg a cleaner city and more desirable as a place of residence. These are factors in the making of a truly Greater Pittsburg. The building of a metropolis must consist of a more healthy and substantial growth than accrues from the annexation of surrounding villages and pasture fields.

PNEUMATIC LOCOMOTIVES.

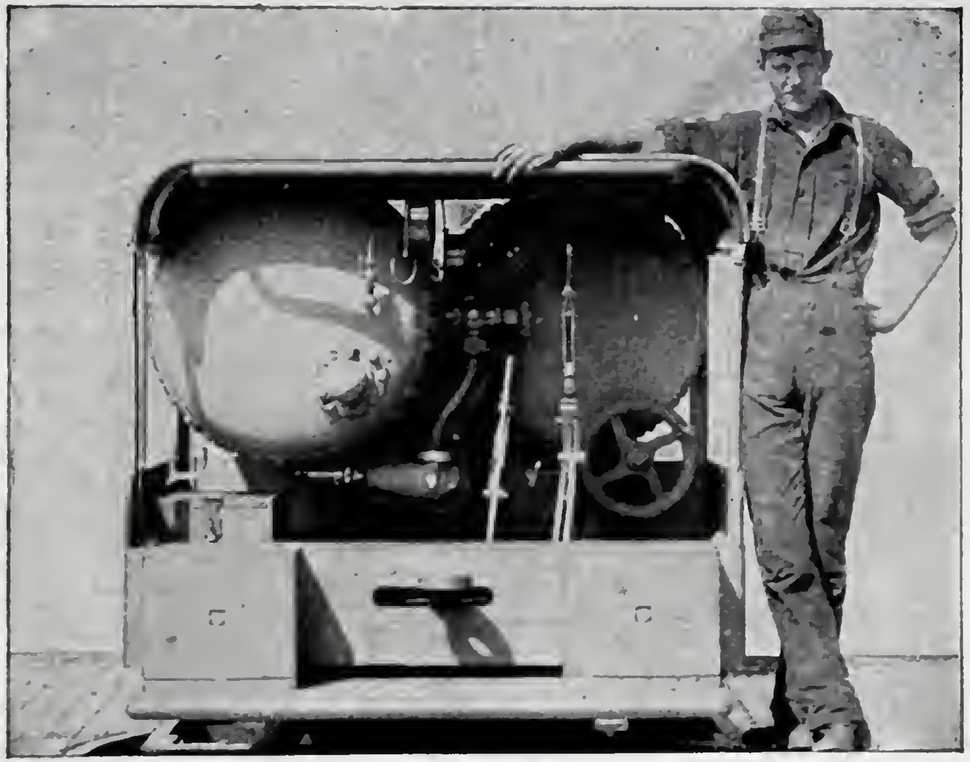
Compressed air has been used with great success in the operation of locomotives. When used for operating street cars or for hauling trains through tunnels or city streets, all the advantages of an independent motor are obtained with

none of the objectionable features of steam locomotives or electric cars. It is especially applicable in locations where sparking electric wires, fire and fumes of combustion must be avoided.

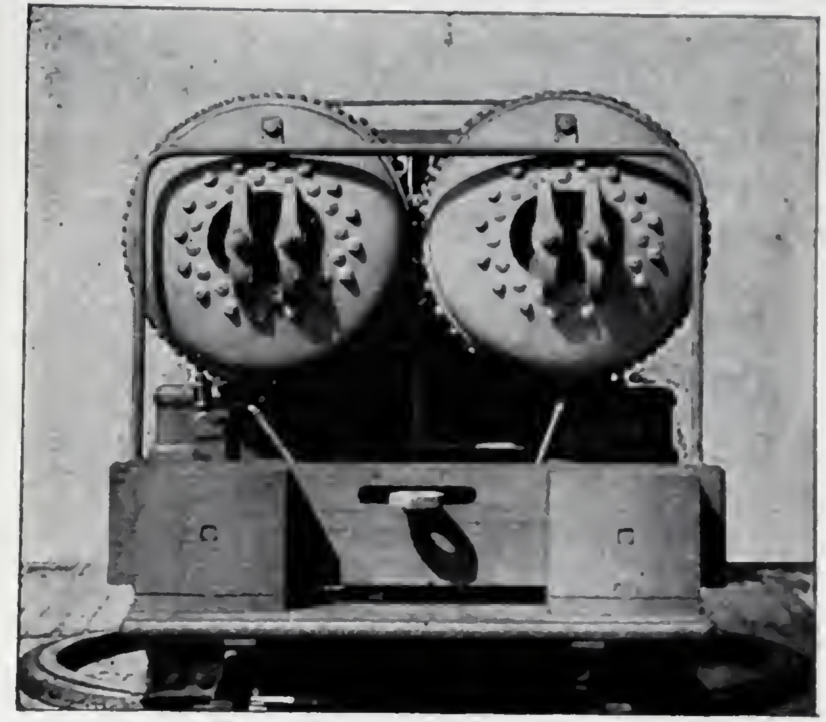
The following is a very brief description of the plant of the Susquehanna Coal Co. at Glen Lyon, Pa., where there are two motors in operation, one of which is illustrated on a preceding page. The air is supplied by a compressor of the three stage type, having steam cylinders 20 inches × 24 inches, and air cylinders $12\frac{1}{2}$ inches, $9\frac{1}{2}$ inches and 5 inches × 24 inches, with water jackets and intercoolers, compressing the air to 600 lbs. per sq. in. The air passes through a line of 5 in. special strong pipe 200 feet to the head of the shaft, down the shaft 800 feet and then along the gangway about 3,400 feet, a total length of 4,300 feet. This pipe line has a capacity of 580 cu. ft. and acts as a reservoir for the compressor. It is coupled together with threaded sockets which are counter-bored for a lead filling which is caulked. At intervals of about 200 feet, and at all valves and charging stations, flange couplings are used with lead gaskets, and the line is perfectly tight, being tested to 1,500 lbs. per sq. in. Charging stations are placed where required, and consist of a universal metallic coupling, which is attached to the check valve of the locomotive air tanks when a fresh supply of air is required. It requires about $1\frac{1}{2}$ minutes to complete the operation of charging the locomotive, and reduces the pressure in the main pipe line from 600 lbs. per sq. in.. to about 570 lbs per sq. in. A charge of air weighs about 380 lbs. The locomotive is of the four wheel type, having cylinders 7 in. diameter by 14 in. stroke; drivers 24 in. diameter; weight 18,500 lbs.; length over all, 17 feet., 6 in.; width, 5 ft., 2 in.; height, 5 ft., 0 in. The air for propelling the locomotive is stored in two cylindrical steel tanks with a combined capacity of 130 cu. ft., and are supported by cast iron saddles resting on the frames of the locomotive. The air flows from the main



Side Elevation.



Rear Elevation.



Front Elevation.

Pneumatic Mine Locomotive.
Built by H. K. Porter & Co., Pittsburg, Pa.

tanks through a specially designed reducing valve into an auxiliary reservoir, and from thence through a throttle valve to the cylinders. The pressure in the auxiliary reservoir can be regulated anywhere from 30 lbs. up to 140 lbs. or 150 lbs. per sq. in. as required. The air in the auxiliary reservoir is maintained at a constant pressure, while in the main storage tanks it may vary from 570 lbs. per sq. in. down to the pressure at which the reducing valve is adjusted; when this pressure is reached in the main storage tanks, the air passes through to the cylinders without further reduction in pressure.

The locomotive hauls 16 empty cars a distance of 3,700 feet into the gangway and returns to the shaft with 16 loaded cars with one charge of air, starting with a pressure of 575 lbs. per square inch and ending with about 100 lbs. per square inch. The train of empty cars, including the locomotive, weighs 60,000 lbs., and the train of loaded cars, including the locomotive, weighs 166,000 lbs. The grades favor the loads. The locomotive runs from 25 to 50 miles per day, depending upon the length of trip and time consumed in making up the trains at the terminals. This locomotive was lowered down the mine shaft a vertical distance of 800 feet without dismantling in any manner. Sometimes the circumstances are such that it becomes necessary to take the locomotive apart, lower it piece by piece and reassemble them in the mine.

Where it is practicable to use a heater on a locomotive, the efficiency is increased about 40 %. These heaters take the place of the auxiliary reservoir, and consist of a tank containing hot water under pressure at a temperature of about 300°F., through which the air passes before going to the cylinders. The heaters are charged with steam while the storage tanks are being charged with air.

Compressed air is also used for the propulsion of street cars, the air being stored in nests of Mannesman tubes. There are four of these tubes under each car seat, and are 9 inches in diameter by 15 feet long, and are charged to a pressure of about

2000 lbs. per square inch. The air is reduced in pressure by a reducing valve to about 140 lbs. per square inch and then passes through a hot water heater and throttle valve to the cylinders. The cars are of the four-wheel type, have the ordinary street car body and are provided with the usual locomotive machinery, reversing gear, balanced valves and air brakes. They can be controlled from either platform by means of a fixture similar in appearance to a trolley car controller, and very compact. They are independent motors, have all the advantages claimed for storage battery cars, and compare favorably with the overhead trolley system in cost of operation.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

DISCUSSION OF THE PAPERS OF MESSRS. STEWART, WILKINS AND HIRSCH AT THE REGULAR MEETING OF APRIL 20th, 1897.

MR. ALBREE. I would like to ask, when you have 140 pounds pressure in the cylinder, if you have any trouble with freezing?

MR. HIRSCH. The moisture in the pipe is all drawn off. The cylinders may be covered with frost on the outside, but we have experienced no difficulty with freezing, although the pipes get very cold, particularly when the pressure is being reduced.

I would also state, that I think but very few people know what they are paying for electric power. The electric companies in Pittsburg to-day charge 12 cents for 1,000 Watt hours, which amounts to $482 per horse power per annum of 3,000 hours; an exhorbitant price for power. There is surely a field for a power company in Pittsburg.

MR. A. KIRK. I suppose we are all expected to give some of our experiences with the use of compressed air. I have had a good deal of experience in running rock-drills with steam and compressed air, following the use of steam with air in the same machine; and experience shows that the same machine, under the same conditions, will do from six to ten feet more hole in the rock per day with compressed air than with steam. I was a good deal puzzled to account for that, but I think now that it was very easily accounted for. The ports in a steam drill are very small, and with the pressure of it at right angles almost, and with a more or less watery

friction of the steam, it don't exhaust in advance of the piston as quickly as air does. In starting a drill I noticed that the compressed air caused a stronger blow to be struck and produced more vibration in the rock than steam did.

I might also relate a curious circumstance which occurred in running a duplex compressor. The experiment was carried on near Ligonier by a very intelligent engineer, a practical man. He demonstrated that with a duplex compressor with eighty pounds of steam there were eighty-five pounds of compressed air. The cylinders were exactly of the same diameter.

President. That is certainly a very curious circumstance, Mr. Kirk.

Mr. A. Kirk. It is certainly a curious fact, but it was demonstrated to our entire satisfaction. The engineer of whom I am speaking, who, by the way, is a natural genius, was surprised to find that the pressure gauge showed a difference every time when the machine was allowed to run up to its full capacity, and he changed the gauges, as he thought it might be caused by a variation in the gauge, but the result was the same. It was demonstrated to be a fixed fact. The only reason he could give for it was that in running a duplex engine the escapement of the pressure in addition to the returning stroke of the piston is so complete that the momentum of the piston and the fly wheel actually caused a stronger pressure than the steam does.

Mr. Bole. It has not been said that there is *more work* done in the air cylinder than in the steam cylinder, but only that the *pressure* may be, under certain conditions, *higher* in the air cylinder than it is in the steam cylinder which impels the pump. This has been observed in the locomotive air pumps which are in general use in this country. These pumps are not duplex and have no fly wheel. It is possible to run when not much air is being used with one hundred pressure in the boiler and obtain an air pressure considerably higher than one hundred pounds, this effect being due to the weight of the

movable parts. These parts absorb energy during the early part of the stroke and give it up at the end of the stroke, thus enabling the air pressure to rise higher than the original boiler pressure. This is when the air cylinder and steam cylinder are of the same diameter.

As discussion on the two previous papers is more or less in order, (that is, Prof. Stewart's paper on the Gas Engine, and Mr. Wilkins' paper on Electricity), I suppose the members are free to speak on those papers, as well as upon the paper which has been read this evening.

I do not think that Mr. Hirsch, in presenting his paper this evening, offers anything very tempting, from a financial point of view, to the investing public. I do not say this in criticism of his paper, but I want to draw out the facts.

It has been stated, in his statement of expenses, that the *fuel cost* of operating eleven hundred horse power plant would be $5,000 per year, out of a total cost of operating expenses amounting to $60,000. The cost of fuel is often taken as a measure of the total cost, but placing the cost of the fuel at $5,000, this item is insignificant when compared with the total cost of his power. He must sell the power, as he proposes, for $40.50 for service alone. Later he tells us that it will cost the user $50, including interest on cost of motor, cost of heating the air, and cost of the necessary attention required. On a basis of selling the air to the public at $40.50, there does not seem to be anything in it for the investor but the mere 6% on the investment, which might be easily wiped out by unexpected expenses resulting from accident, or damages of various sorts.

I would like to know, as a member of the Committee on Power, and would ask Mr. Hirsch to enumerate the specific uses to which he would expect buyers to put this power, and to write them on the black-board. I would also ask him to give us an idea of the different uses to which air could be applied in some of the large buildings in this city, such as the

Carnegie Building, or, perhaps, the store of Jos. Horne & Co. I imagine that he would find that the greatest use for this power in one of these buildings would be to produce *electricity* for light or other purposes, and to produce this by the use of compressed air motors would seem, to a certain extent, to be doing work twice.

Where power is wanted in any considerable quantity, it seems to me that our friend, the Gas Engine, still has an equal show with any other such system as this.

MR. A. KIRK. I might give a little experience regarding the transmission of compressed air through a considerable distance. We were working in a stone quarry on a pretty large drill, I think it was 3½ diameter, if I mistake not. The quarry was started within a hundred feet of the compressor. We worked there for some time, but a change in the strata of rock showed the rock contained too much silica for furnace purposes, and we had to go nearly a mile and a half away from the compressor and begin operations again. We were contemplating, and even made arrangements, to move the compressor nearer to the new quarry, but the compressor was in a very convenient locality, near to other machinery, and if it could remain where it was it would save the expense of an independent engineer, and save the trouble of carrying coal and water. I finally insisted that it should remain where it was, stating that we could pipe the power to where we wanted it. This was done, and we found that we could use the compressed air through a 1½ inch pipe to as much advantage a mile and a half away from the compressor as we could within a hundred feet of it.

MR. HIRSCH. In replying to Mr. Bole's question regarding the uses of compressed air, I would say, that it could be used for all purposes, where gas or steam engines or electric motors are now used, particularly in the smaller class of shops. In the city of Paris there are many small users of power who used compressed air, and a great many workmen use

it in their own homes; tailors for instance. I hardly think it is necessary to go to the blackboard to enumerate all the uses to which it could be put, but I would state that the increase of the use of compressed air has been very rapid in Paris. It started in a small way by a system for regulating clocks by compressed air, which was operated from a central station by sending an impulse of air at certain stated intervals through mains in the streets. These mains were pipes of small diameter and were connected to small cylinders located in the clocks to be regulated. The impulses of air operated a piston in the air cylinders which imparted motion to the clock and at the same time kept it regulated with a central clock. This insured uniformity of the time in railway stations, etc.

From this beginning there arose a demand for compressed air for power purposes, which constantly increased until the last air mains which have been laid are twenty inches in diameter, with a compressing plant of 8,000 horse power, and 2,000 horse power in reserve, making a total of 10,000 horse power.

It is very difficult to make an intelligent comparison, using the system of Paris as a basis, because the conditions are so different as regards the cost of coal, labor, etc.

Speaking of gas engines, there is no one who thinks more of the gas engine, or electrical machinery, than I do. I think there is room for both and for compressed air also. There are many uses to which compressed air might be put in which neither gas nor electricity could profitably be used, aside from mere operating of motors. For instance, in railway shops it is used for cleaning purposes, such as car cushions, etc. In the Westinghouse shops it is used for the cleaning of valves, brake apparatus, etc. It is used also for conveying sand to fill the sand boxes of locomotives. In Pairis they use the exhaust of motors for cooling purposes. I have read of a café in Paris where they use the power for light and other purposes, and then finally cool the beer by the exhaust air from the motors.

In the early history of the Niagara Falls Power Company no less a man than George Westinghouse, Jr , said that compressed air would be the only means of conveying power to any great distance; but the possibilities of electricity have been studied so exhaustively, and by so many eminent men, that wonderful progress has been made, and seeming insurmountable obstacles have been removed. I believe that the same amount of study and investigation bestowed upon the subject of compressed air would result in just as wonderful progress.

(Diagram on blackboard, in which Mr. Hirsch showed how the amount of energy required for compressing air varies with the pressure, and the relative economies of using high and low pressures.)

PRESIDENT. Mr. Hirsch refers to the advantage which compressed air offers to the users of a small amount of power. So far as Pittsburg is concerned, we have few small industries here like they have, for instance, in Paris. Pittsburg industries are almost all on a large scale. In this country, I should think compressed air might find a profitable home in some of the manufacturing cities of the east, where jewelry or small articles are manufactured, for instance in Philadelphia or Providence.

MR. HIRSCH. The introduction of compressed air in Pittsburg might prove a factor in the development of many small industries here, and thus be of direct advantage to the city.

MR. FESSENDEN. I have read that a number of compressed air motors have been recently taken out in Paris and electricity substituted in place of them. I would ask Mr. Hirsch if he knows anything about that?

MR. HIRSCH. It is very difficult to obtain any literature on the subject, except what appears in the engineering papers, and but little is to be found in them during the past two or three years. But I do not know, nor have I heard, that electricity was superseding the use of compressed air in Paris.

A member here asked what progress was being made with the compressed air tramways now used in France.

Mr. Fessenden. I think that the statistics for last year in France show that the roads operated by compressed air number two less than the previous year, while there are eleven new electric railroads. I think this one indication of how things are going. Another is that the Popp system in Paris has been virtually abandoned; that is to say, I understand that in place of delivering air in Paris the way they used to, directly to the motors, they are now using the compressed air to drive electric generators, and furnish electricity to the houses where they formerly supplied the compressed air.

I would like to ask if Mr. Hirsch has not placed his efficiencies rather high. The Colliery Manager's Hand-Book gives from twenty-five to thirty per cent. for mining plants. I think 750 horse power resulting from an indicated 2,000 horse power in the steam engine cylinder would be about what is usually obtained. There is a loss of ten per cent. from friction, and the inevitable losses from compression, and then allowing fifteen per cent. from leakage and the loss in the motors from expansion and friction, the actual horse power resulting could hardly amount to more than 700 or 800 horse power, costing up to eighty dollars per horse power.

Since Mr. Wilkins' paper is also up for discussion I would say that so far as electricity in mining is concerned recent developments have greatly increased the possibilities of using this power in mines, and reduced the danger to a minimum. Since the discovery of the two phase and three phase motors, there is not the least danger of sparking. There have been some difficulties met with as regards starting torque, but we are now able to get better starting torque with polyphase motors than can be obtained with the best series motors of equal rated capacity on the market.

There is absolutely no sparking from brushes, nor need there be from fractured conductors, as with concentric cables we have no ground return.

This, (sketching on the blackboard), represents one conductor. This is another, concentric with the first, and protected from it by insulation. In addition to the insulation, outside the third wire we wind on heavy iron wire, as a mechanical protection. If it be broken, it is so arranged that the circuit is first broken on the inside wire, the outer tubes being made from strips twisted, and so any arc is inclosed and merely produces a short circuit, throwing the circuit breaker. All connections to machines can be made safe by using a device which I have designed so that the terminals and plugs go to boxes filled with oil and automatically closed by a float in case of leakage of the oil. These connections are absolutely free from all danger of sparking.

I would say that I think we are all very much indebted to Mr. Wilkins for his paper, which contains so much valuable information. There are, however, one or two points to which I would take exception. I do not think that Kelvin's law is a safe one to follow. It is misleading because it gives the best size conductor to transmit a given amount of current, and not the best size for transmitting a given amount of power.

Another point is in regard to speed. For myself I prefer a a high speed machine. There is no reason why an armature should be run at a less peripheral speed than two miles a minute. In such a case the price will be much smaller and the efficiency much greater. I think we shall soon see a reaction against the present slow speed units. It is worth noting that the cheapest supply of electricity generated by steam in the world is at Newcastle, Eng., four cents per H. P. hour or $\frac{1}{4}$c per lamp hour, and that here the highest speed units in the world have been run for five or six years now.

The last point is, that I think it would be a good idea to put screens, fans, and all such machinery on the electric plant, as the power units are always most efficient when fully loaded, and by so doing we can always adjust the load from one dynamo set to the other so as to keep all sets at their most economical running point.

Mr. Hirsch. Replying to what Prof. Fessenden has said with regard to my placing the efficency too high, I would say that the builders of the compressors will guarantee the capacity as given in the paper, and I made due allowance for loss in transmission in the mains by leakage and friction. The amount of air available at the motors for useful work was thus obtained. The amount of work which this air is capable of doing was calculated, and the result verified by extensive experiments and tests which have been made in our shops to determine how many foot-pounds of work each cubic foot of free air will do under regular working conditions. When you (Prof. Fessenden) say that Prof. Unwin gives 40% as the efficiency of transmitting power by compressed air, I would ask if that is not the result obtained when using the air cold and under favorable conditions, such as very long distance? Under favorable conditions, and by heating the air before using in the motors, Prof. Unwin states that efficiencies of 70% and even higher, can be obtained.

I would also ask Prof. Fessenden with reference to the use of electricity in mines, as to how it is possible to avoid sparking from trolley wires?

Mr. Fessenden. That is one thing I forgot to mention. I do not think we can ever use a trolley in a fiery mine. In such a mine, electricity can be profitably used, however, in conjunction with cable haulage and compressed air, using electric motors for driving the cables, driving them by polyphase motors, placing small motors underneath the track at bends and wherever necessary. They would automatically adjust themselves. Electric motors can also be used to drive small compressors for working compressed air drills, as electricity cannot work percussively to advantage, and thus electricity, cable, and compressed air would combine to do more efficient work than perhaps any of these methods alone. Of course this is only a suggestion. I do not know how it would turn out in practice without studying the subject further, but think it promising.

Mr. Stewart. I would like to ask Mr. Hirsch about the efficiency of the air referred to when running less than full load, say at one-half or one-quarter load. In my paper on the gas engine, I gave the cost per horse power of $15 and some cents for power generated by gas engine when running under full load and also gave cost when running under one-half load and one-quarter.

Mr. Hirsch. The compressing plant and isolated motors would be fairly worked up to their full capacity. You pay for the air by meter.

Mr. Stewart. Am I to understand that the estimate given by Mr. Hirsch is for the motor running under the most favorable circumstances; that is, under full load? As I stated, it costs more per horse power to generate power when running under anything less than a full load. Gas is paid for by meter also.

Mr. Hirsch. I just took the price of the air, as paid for by meter, at so much per cubic foot; did not take into consideration that motors would be running at anything less than their full capacity.

Mr. Davison. Mr. Wilkins wishes to have added to his paper an estimate of the cost of installing an electric mining plant, but I will not take time to read it in detail. The amount of the estimate is twenty-two thousand dollars. He also submits the cost of mining coal by the use of such a plant in comparison with hand mining prices. The estimate of cost of mining with electric machines includes the interest on the cost of twenty-two thousand dollars, the wages of the men employed, and all incidental expenses, including the cost for loading the coal after it has been mined. There are two estimates given; one on a basis of mining eight hundred tons of coal daily, and the other on a basis of mining four hundred tons of coal daily in Pittsburg district. He wishes to say that both of these estimates were the actual figures submitted by concerns installing such plants under a guarantee that the

operating prices would not be exceeded. Without going into the details of the estimates I might say that on a basis of mining eight hundred tons per day by electricity, the cost would be fifty and one-tenth cents per ton as compared with the cost of seventy cents for hand mining. On a basis of four hundred tons per day, the cost would be fifty-two and seven-tenths per ton as compared with the cost of seventy cents for hand mining.

ESTIMATE OF COST OF ELECTRIC MINING PLANT.

The following is an estimate of the cost of installing an electric mining plant to produce eight hundred tons daily of 1½-inch coal in the Pittsburg District. The estimate is based upon eight chain machines, undercutting five feet, and allowing 100 lineal feet per shift for a machine, with an average thickness of coal mined of five feet, which would make about ninety tons run of mine coal per machine per shift, so that eight machines making two shifts, would produce 1440 tons of run of mine coal.

Allowing 60 per cent. for 1½-inch coal we would have 864 tons, or say 800 tons 1½-inch coal, as a fair day's work for eight machines, or sixteen machines working single shift.

ELECTRIC PLANT.

Eight 6′ Machines	$ 9,600	
One 100 K. W. Generator	2,000	
One 15″x16″ Engine	1,200	
One 16″ Double Leather Belt	150	
One Electric Emery Wheel	250	
Twenty Lamps	20	
Services of Engineer 4 months	650	
Eight 250 ft. Cables and Reels	360	
One Switch Board	300	
Wire	1,628	
Freight	300	
		$16,458

BOILER PLANT.

Two 150 H. P. Boilers complete. .	$ 2,700	
Boiler and Dynamo House.	1,400	
		$ 4,100
		$20,558
Add 5% for supt. and contingencies		1,028
Total		$21,586

Or say in round numbers, $22,000.

COST OF ELECTRIC MACHINE MINING.

Estimate of cost of mining 800 tons 1½-inch coal in a mine in the Pittsburg District, working eight electric chain machines twenty hours daily, or double shift. Hand mining rate being 70c, loading ½, or 35c per ton.

Two Engineers (day and night) at $2.50. . . .	$ 5 00
Two Blacksmiths at $2.50	5 00
Two Blacksmith Helpers at $2.00	4 00
One Bit Grinder	1 50
Four Bit Boys at 75c.	3 00
Sixteen Machine Men at $2.25	36 00
Sixteen Machine Helpers at $2.00	32 00
Oil and waste	3 00
Repairs, depreciation and steel for new bits in 800 tons at 2½c	20 00
Incidentals and wire extension	5 00
Interest on plant, say on $22,000 at 6%	4 00
One Electrician and Superintendent	3 00
	$121 50
Loading, propping and blasting in 800 tons at 35c	280 00
Total cost of 800 tons	$401 50

Or per ton.	$0.501
Cost of hand mining	.70
Saving by machine mining per ton	$0.199

Lump coal estimated at 60% of run of mine.

On a basis of only 400 tons per day being mined, the cost would be as follows:

Two Engineers at $2.50	$ 5 00
Two Blacksmiths at $2.50	5 00
Two Blacksmith Helpers at $2.00	4 00
Two Bit Boys at 75c	1 50
Electrician and Superintendent	3 00
Eight Machine Runners at $2.25	18 00
Eight Machine Helpers at $2.00	16 00
Oil and waste	5 00
Repairs, etc., at 2½c per 400 tons	10 00
Interest per day on cost of plant	3 30
	$ 70 80
Loading, propping and blasting 400 tons at 35c	140 00
Total cost of 400 tons	$210 80

Cost per ton by hand	$0.70
Cost per ton by machine	.527
Saving by machine per ton	$0.173

President. Mr. Schellenberg. Have you anything to say on this subject of mining by electricity and the cost of the various items?

Mr. Schellenberg. I have heard a good deal about mining coal by electricity and I think a good deal of money has been invested, but personally I do not know of any place where it has been an economical success. They use the air still, where it was installed 15 years or more ago, and where the undercutting bears a proportion of about 50 per cent. of the whole work. Mining by this method was economical a few years ago, but is scarcely now as the cost of labor is so low.

President. Can you give us any comparative figures?

Mr. Schellenberg. The hand mining rate is about 60

cents for 1½-inch coal per ton. It was considerably higher. It is about a stand-off now; in mines where the undercutting bears a proportion of 50 per cent. of the whole work done it should begin to be advantageous to use the power machine.

PRESIDENT. Very naturally, as the undercutting is the hardest part of mining.

MR. SCHELLENBERG. Yes, and that is the kind of work a hand miner cannot work at continuously and the machine can. Ten hand miners, who take down and load up the coal they have undercut, are displaced, as to this undercutting, by one pick-mining machine. It does half the work, therefore, of ten miners if, according to the height of the coal seam and hardness of the bearing in, this is 50% of that total work of getting the coal—which should, however, be considered as including the setting of posts and disposing of slate. When any type of machine enlarges and lengthens in its striving to exceed in depth the miner's reach of three or four feet under, it has to have more room in front of the face to start, and the slate has to be handled further back to gob; then the deeper undercutting induces more general blasting down of coal which easily spoils what would be lump if it had been brought down by wedging, as hand miners working to make lump get their coal ordinarily, using powder only in hard places.

I have a respect for the good judgment of the miner who keeps his working place tidy and himself safe according to the natural conditions and the facilities allowed him, and he can prove himself a skilled miner still, if given a power tool that he steers in, simulating the well directed blows of the pick as he lets it work its way *en echelon* aided by gravity into the solid, and, by guiding only, step its way back again at his bidding. The automatic feed machine cuts faster but the doing of it is surrounded by disadvantages.

MR. BOLE. The questions which Prof. Fessenden and Prof. Stewart have brought up are of great interest to the Committee on Power. There are no two sets of conditions

precisely alike, and the collecting and arranging of the data furnished is a very difficult job. We realized that from the start. For instance, the question as to whether the motor, for which Mr. Hirsch estimated ninety per cent. efficiency, was run up to its full capacity, and what its efficiency would be under work less than its full capacity. Will a twenty five horse power motor of Mr. Hirsch, while working down to fifteen horse power, still give ninety per cent. efficiency? It will not. The cost of operating this motor will not be in direct proportion to the amount of power used. Again, we must go back of the motor to the power house. If the motors are not running the full capacity the compressors in the power house must slow down and lose some of their efficiency.

It is a very difficult matter to get much reliable information from users of power. As a matter of fact, ninety per cent. of the users of power do not know what it costs them. A man buys one hundred horse power engine and boiler, and ever afterwards considers that his factory uses one hundred horse power, where, as a matter of fact, he may not be using anything like that amount of power. Very few users of power know how much power they are using, or what it costs them.

Mr. Stewart. Regarding the efficiency of the motor for which Mr. Hirsch assumed an efficiency of 90%, I would like to ask what he means by that. Is it the efficiency of the working fluid, or the combined efficiency of the working fluid and the mechanism?

Mr. Hirsch. The ninety per cent. efficiency spoken of as high, is only in the mechanism of the motor, and not of the motor and fluid combined. We know from actual tests what each cubic foot of free air will do in the cylinder of the motor in foot-pounds, and there is no necessity for making any assumptions in regard to the efficiency of the working fluid.

President. I suppose the question of what power is best and the most economical depends largely on the purpose

for which you want to use it, as much as upon the actual cost. In some cases air, although costing more per H. P., is used for other reasons, as, for example, being more convenient. In other cases electricity is undoubtedly the most convenient power to use without reference to its cost. Air is certainly a very good thing to use in shops where you have very heavy pieces of iron to move about from one place to another, for instance in boiler and bridge works. It is better to use than electricity as there are no wires to interfere with your work; in other places electricity is the more convenient power.

Mr. Fisher. I would like to ask Mr. Hirsch what the efficiency of a one-horse power motor would be? With large electric motors we get a greater efficiency than with smaller ones.

Mr. Hirsch. I could not say from experience.

Mr. Fisher. I wish to bring out a comparison between electric motors and air motors. The efficiency with large electric motors may be 80%, whereas in the smaller motors it runs down to as low as 45, 50 or 55%.

Mr. Bole. I think the discussion is resolving itself into something like one which took place in a debating society to which I belonged as a boy. The subject was, "Which is the more useful animal, the horse or the cow?" It depends entirely upon what you want to use it for.

President. Speaking of small air motors, I think there is a great difference in their efficiency. I have just had some experience with them during the last two days. One motor required a good deal of pressure to operate it, and the other could be operated by blowing into it.

Mr. Stewart. Comparing air engines, gas engines, and steam engines, it is said that the efficiency of both gas and steam engines lessens rapidly as the size is lessened. And what we want to know now is how the size of the air motor effects its efficiency. I believe a very small air engine is very inefficient on account of the excessive friction.

The special meeting of the Engineers' Society of Western Pennsylvania, for the purpose of considering H. R. Bill 9866, was held in the lecture room of the Society's house, Tuesday, March 30, 1897, the President being in the chair. The meeting was called to order at 8.20 P. M. There were 38 members and visitors present.

As this was a special meeting, the reading of Mr. Morse's paper was at once proceeded with.

THE DALZELL BRIDGE BILL.

On January 7th Mr. Dalzell introduced a bill in Congress governing the construction of bridges across the Ohio, Monongahela, Mississippi, Great Kanawa, Tennessee, Cumberland and Illinois Rivers. The Pittsburg papers mentioned it next morning in brief outline and on the same day a letter was addressed to Mr. Dalzell and one to the Secretary of the Engineers' Society of this city, stating briefly that the bill as presented should not be passed.

On January 16th, I was requested to read a paper on the subject before this Society, and (knowing that the Bill would not be passed that session of Congress, but would be re-introduced) I consented, though I regret that I could not spare time sufficiently to give so important a subject the attention it should receive.

Forty-six years ago there was not a single railroad system entering Pittsburg. To-day the valleys of the Allegheny, Monongahela, Beaver, Ohio, etc., literally swarm with important systems, handling their millions of tons of freight and thousands of passengers annually. So completely do the present railroads line the banks and shores of these natural arteries of commerce that one of greatest value to Pittsburg's future, now building, has been projected "cross-country," at vast expense. This is a great railroad center, enjoying some of the best systems of the land, and if others want to come and share the enormous tonnage of this vicinity they must also be built

"cross-country,"—crossing and re-crossing our water ways. Shall we, as progressive engineers, stand idly by and make no protest against legislation that will please the navigators but prohibit the building of any more railroads that would have to cross the Ohio? That is just what the Dalzell Bill means. I name it thus, simply because Mr. Dalzell introduced it. The bill was written by the Pittsburg Coal Exchange.

The rapid expansion of railroad construction and the connecting together of our important cities, North and South, East and West, necessitated the building of bridges over our important rivers, among the first being the Ft. Wayne over the Allegheny River at Tenth Street, the Panhandle over the Monongahela at Try Street, and the Steubenville and Bellaire bridges over the Ohio River. The early bridge builders in this vicinity made no systematic attempt to provide a longer span for a highway than for a railroad bridge; and a span approaching 300 feet was about the limit of construction for fixed spans.

Roebling built a few long span suspension bridges which were not duplicated. Sad as was the Ashtabula disaster, it was the great cause of the greatest impetus of the now world-wide reputation of American bridge building. The use of cast iron was abolished and wrought iron was substituted, but this was not all. Every first-class railroad to-day has a competent bridge engineer. Twenty years ago I was a draughtsman in my brother's bridge shops and we had but two specifications on file for railroad bridges. One was Charley Latimer's, of the N. Y. P. & O., and the other was (I believe) Mr. Slattaper's, both instruments of torture, kept in the safe and only brought out on rare occasions. But so changed are conditions at present, that no bridge company thinks of beginning shop construction without specifications on file. All this has a direct bearing on the subject before us, as it led up to the introduction of systematic inspection and construction of bridges; and before the introduction of steel, the excellence of wrought iron and the better knowledge of its uses, enabled

the engineers to design and build 400 feet double-track railroad bridges. Just at that time our chemists and mill men introduced steel sufficiently cheap for commercial uses; and this, with cheaper construction, and with the cantilever and curved top chord forms of bridges, gave the engineer a new lease of life which will soon, if it has not already, come to a halt. The present limit of length for double-track railroad spans is about 600 feet, within the bounds of reasonable cost; and for highways 1,000 feet. The engineer must resort to one of two things if the growth of long span structures be carried forward as rapidly as it has been in the past:

1st. The introduction of the suspension bridge; which can be built with less expense for very long spans than any other type now known. But the suspension bridge does not meet with the same favor as our present construction; and it would be uphill work to persuade any of our railroad chief engineers to adopt a suspension bridge costing a million or two of dollars. The utility of modern suspension bridge building must first be demonstrated in highway construction, where an error is not so vital and where the cost of construction is reasonably moderate, before the chief engineers of railroads can be expected to adopt them. And even after they might be considered as standard, I doubt if they would be used except where the cost of fixed spans of the present type would mount up to a lavish and questionable outlay of money. In short, I believe the use of suspension bridges will only figure as a last resort in railway construction. On the other hand, I consider the suspension bridge, constructed on modern ideas for long span highway bridges, as entirely proper.

2d. To wait until our brother engineers, the chemists, furnish us a compound of aluminum of commercial value, light as possible and strong as steel, or make steel in large sections that will have twice or three times its present strength. When they can solve these hard problems, long span double-track railroad bridges can be designed and built. With materials

now available they are so massive that the greatest task for the designer is how best to make them support their own weight. With the present forms and use of steel in the construction of double-track railroad bridges, 600 feet is about the limit of length for a span, for two reasons: First, the cost becomes so great that few companies can make such an expenditure of money; second, the sections of a double-track railroad bridge over 600 feet long, of the ordinary design, are so large that the plates, bars and shapes of which they are composed, must be of excessive size and weight; this increased section decreases the quality so much that they would never be accepted by an inspector of materials under modern requirements. Then, too, there is little demand for such materials and construction; which means additional cost to railroad companies. Could a form of aluminum be brought into commercial use, having the properties of wrought iron or steel, all this would be different; and America would surprise and lead the world again, as she has of late, in design, boldness of construction, perfection of workmanship, length of span and miles of bridges built.

Rapid as has been our pace, we are not prepared to double it. Keen competition and great freedom and latitude in design have won for this country the distinction of building the most long span and the best designed double-track railroad bridges of any country in the world, but we are not prepared to suddenly jump from a 500 foot to a 1,000 foot clear span. I do not say it cannot be done—it can be. Money will accomplish it. There are engineers in our midst eminently fitted to carry on to completion such stupendous constructions with ability that would make us justly proud, but where is the engineer who would for one moment allow his company to consider the bridging of the Ohio River with a 1,000-foot clear span when an equally good location could be found that would not interfere with navigation and not require over a 500 or 600-foot channel span. The rapid decline of the erected pound price of iron and steel bridges, compared with that of masonry, has been

a constant stimulus to the building of longer span bridges, which cannot, however, be augmented by legislation. There is not a single double-track railroad bridge in the United States of America of a 1,000 foot clear span, and but one of 800 feet—the suspension bridge at Niagara Falls now being replaced.

These great evolutions in construction must come logically and naturally, and will not admit of forcing. The passage of the Dalzell Bill will stop all railroad enterprises which contemplate crossing the Monongahela or Ohio Rivers for years to come. Who knows how long? Just think of enacting a law prohibiting any railroad crossing the Ohio River, which is 967 miles long, for an indefinite period of years, except under conditions that would necessitate two or more railroads pooling their interests and combining and dividing the unjust cost of excessive bridge construction. I claim that no railroad, single handed, could afford to build into this vicinity and meet the expenditure which a 1,000-foot clear span would necessitate. Imagine one's frame of mind if the proposed location was at a narrow point in the river and both piers were clear of any point ever reached by navigation, or if an island was in the river and a 1,000-foot clear span, which the law demanded, would span the island, the channel and all, thus necessitating an excess outlay of $500,000 to $800,000 (or even more) beyond what would be required were a pier allowed on the island and no pier placed in the channel navigable at any ordinary stage of water. Yet such is the meaning of the Dalzell Bill.

Why was this bill introduced? Here is withal a sad history, too long to relate, though it must be dealt with in a condensed form. Scarcely fifty years ago the rivermen had everything to themselves. There were no bridge piers and nothing else to mar their pleasure, except the bars. In the early spring of 1852 the first freight shipments by rail out of Pittsburg began, and in 1895 they had increased from nothing to the enormous figure of 35,000,000 tons, during a period of forty-five years. In 1852, the coal shipment down the

Monongahela (and there was no other of any consequence) was 14,630,841 bushels, or 562,725 tons; and in 1895, 104,589,-900 bushels, or 4,022,682 tons of coal, which is an increase of only 3,419,959 tons; just one-tenth of the railroad increase for the same time. Shall this society demand the passage of the Dalzell Bill, prohibiting railroad construction? Hardly!

Let me call your attention to the following exhibit marked No. 1:

"Statements of all coal shipments through Monongahela Navigation Company's Locks since the completion of same, November, 1844, and tolls received from coal and other sources, including empty crafts, timber, iron, iron ore and other freights:

Years.	Bushels Coal.	Tolls Paid on Coal.	Tolls on Empty Crafts, Coke, Freight, &c.
1844	737,150	....	....
1845	4,665,185	$ 3,383 79	....
1846	7,778,911	10,221 28	....
1847	9,645,127	13,241 94	....
1848	9,819,361	12,488 42	....
1849	9,708,507	13,533 30	....
1850	12,297,967	17,623 57	....
1851	12,521,228	17,850 24	....
1852	14,630,841	20,014 18	....
1853	15,716,367	21,291 85	....
1854	17,331,046	25,079 51	....
1855	22,234,009	31,050 58	....
1856	8,584,085	10,566 42	....
1857	28,873,596	37,111 11	....
1858	25,696,669	34,353 49	....
1859	28,286,671	39,065 65	....
1860	37,917,732	50,028 17	....
1861	20,865,722	30,945 92	....
1862	18,583,856	26,709 29	....
1863	26,454,252	40,532 28	....
1864	35,070,917	61,384 29	....
1865	39,522,792	69,698 48	....

1866	42,615,300	77,811 26	....
1867	30,072,700	54,855 63	....
1868	45,001,000	91,376 08	....
1869	52,512,600	104,936 61	....
1870	57,596,400	118,705 68	....
1871	48,621,300	100,338 64	....
1872	54,208,806	115,609 20	$ 80,089 08
1873	56,073,238	116,728 75	89,868 14
1874	65,881,700	137,489 58	77,974 35
1875	61,409,000	133,609 88	61,223 19
1876	62,395,000	139,610 35	72,904 23
1877	79,480,918	149,292 07	78,697 96
1878	76,825,255	133,718 67	69,793 63
1879	65,588,000	110,791 79	63,915 63
1880	89,377,150	155,495 01	....
1881	90,035,360	154,165 39	62,742 71
1882	106,168,300	178,580 42	93,410 83
1883	112,395,389	190,610 22	88,413 64
1884	81,709,852	140,509 78	66,693 19
1885	85,923,107	144,365 43	71,509 88
1886	113,099,147	187,160 26	68,181 57
1887	78,912,900	133,426 02	66,731 06
1888	115,814,900	189,392 41	83,406 16
1889	81,162,500	144,295 85	64,934 08
1890	116,902,600	204,236 64	88,375 86
1891	106,914,700	185,189 37	83,534 33
1892	96,818,350	172,830 18	87,252 60
1893	96,501,000	176,348 98	83,673 15
1894	116,240,313	....	....
1895	104,589,900	....	....
1896	142,731,300	....	....

Subtract for local consumption about as follows :

1890	30,000,000	Practically 25%
1891	25,000,000	
1892	25,000,000	
1894	35,000,000	
1895	40,000,000	
1896	50,000,000	

I spoke before of the history of navigation in this vicinity as being pathetic. One need do no more than make a careful study of this list of shipments and tolls to prove it. During the past sixteen years the river coal trade has increased very slowly, fluctuating back and forward in a way that is feverish, now, however, rapidly declining, while the tolls have been yearly fortunes collected from the rightful and legitimate profits of the rivermen. It is nothing short of an outrage that the Government should allow this taxation to exist one year after throwing open the Kanawha River free of all tolls and 267 miles nearer the Southern market, practically below all the bad bridges and dangerous navigation, and often enabling shippers to slip out with a tow when it would be impossible from Pittsburg. The Government is driving Pittsburg coal out of the Southern market and will accomplish it by unjust discrimination so quickly that the rivermen of this district must suffer still additional losses before they can accommodate themselves to the new condition of things. The purchase by the Government of the locks and dams on the Monongahela would put no less than an average of $180,000 yearly on the right side of the books, from tolls on coal alone.

Civilization brought railroads; railroads built towns; and railroads and towns have necessitated the building of bridges over navigable streams in many places.

Permit me to read you here the following exhibit marked No. 2, taken from the report of the Chief of Engineers, U. S. A., for 1896, showing the reported losses by collisions with piers of the Ohio River bridges to December 31st, 1895, as follows:

Beaver bridge,	$ 56,340
Steubenville bridge,	93,108
Wheeling and Martin's Ferry bridge,	9,800
Bellaire bridge,	140,656
Parkersburg bridge,	77,777
Pt. Pleasant bridge,	9,600

Kenova bridge, ...			20,900
Newport & Cincinnati R. R. bridge,			44,107
Covington & Cincinnati	"	"	93,300
Cincinnati Southern	"	"	9,812
Louisville & Jefferson	"	"	7,800
Ohio Falls	"	"	80,350
Kentucky & Indiana	"	"	27,767
Henderson	"	"	20,520
Cairo	"	"	23,497
Total, . .			$715,334

It is safe to say the direct loss from bridge piers to navigators on the Ohio River alone has reached $1,000,000; and this explains why the suggestion to rivermen of any proposed new bridge has about the same soothing effect as a red rag to a mad bull. A glance at the above list shows that practically every bridge built over the Ohio River has been and always will be a source of loss and a menace to navigation. What answer can these vile railroad bridge piers make? I will answer for them. Few people not in touch with the subject can realize what is doing in the coal situation in the Pittsburg district. It will, doubtless, cause no little surprise that there has been shipped out of this district for the year ending December 31st, 1895, 16,500,000 tons, or a little less than 430,000,000 bushels of coal. Of this amount, 14,000,000 tons were shipped by rail and about 2,500,000 tons by river. Of this enormous tonnage

The P. & L. E. R. R.	carried	4,000,000	tons.
" P. R. R.	"	5,000,000	"
" B. & O. R. R.	"	2,000,000	"
" Panhandle	"	3,000,000	"
" River	"	2,500,000	"
Total,		16,500,000	tons.

LOCAL CONSUMPTION.

The P. & L. E. R. R.	carried	1,000,000 tons.
" P. R. R.	"	1,200,000 "
" B. & O. R. R.	"	600,000 "
" Panhandle	"	800,000 "
" River	"	1,538,000 "
	Total,	5,138,000 tons.

There were 5,529,627 tons of coke shipped by rail.

Before discussing these figures let us pass to the third great source of loss, one carefully guarded, concerning which I could obtain no definite figures,—it is the loss arising from grounding on bars, collisions and carelessness. It would make interesting reading and I am led to believe from hints given that it would surprise most readers. This, however, is claimed to be incident to the trade. But when a pilot is ordered out with a fleet drawing six feet of water on a 5′ 10″ falling river and grounds on the first bar, is it incident to the trade? Were the barges sunk in the wharf a few years ago on Thanksgiving Day incident to the trade? Were the barges and, yes, whole fleets, sunken on Merriman's and Deadman's bars not long since, incident to the trade? Permit me to read the following Government Record of the number of wrecks removed from the Ohio River, from December, 1895, to December, 1896, there being none after the latter date:

Brunot's Island .	2 coal boats	5 barges	
Deadman's Island .	4 " "	5 "	
Merriman's Bar .	7 " "	1 "	1 flat
Hay's Bar . .	1 " "		
Stoop's Ferry .	1 " "		
Sewickley . .		1 "	
Brown's Island .	1 " "	1 "	
Raccoon Bar . .		1 "	
	16 coal boats	14 barges	1 flat
	392,000 bu.	189,000 bu.	1,000.

Boats average	24 to 25,000 bu.	392,000 coal boats
Barges "	13 to 14,000 "	189,000 barges
		1,000 flat
Amt. shipped	83,731,300 bu.	582,000 total losses.

Loss, 7-10 of 1%.

This loss only represents those boats and barges removed on only a short distance of the river; a great many were not removed that were lost, yet you will see by the following exhibit that the losses from piers of bridges average no greater than those from grounding in less than the first twenty-five miles of the Ohio River.

The following tabulated statement shows the amount of coal shipped down the Ohio River after deducting 25% for home consumption since 1860, 1870 and 1880 to 1896, as follows:

Years.	Bushels shipped.	Total loss on piers.	Loss per bushel of coal.
1860-96	1,958,929,818	$1,000,000	0.051 cts.
1870-96	1,696,857,289	"	0.053 "
1880-96	1,158,764,714	"	0.086 "

Average of all, 0.063 cts.

The average of loss should be manifestly closer as represented by 0.051 cents, extending as it does from the first periods to date. This loss is about 1% and equal to the losses on piers of bridges.

Railroads have frequent wrecks and learn to add sufficiently to cover them in their schedule of prices. Why don't the navigators do likewise? The cost of railroad transportations is less and less yearly and their betterments, engines, cars and service, rapidly improving. How is it with the river transportation? Could such a thing be possible that the river interests can no longer stay in the open market? Can they no longer ship coal at a profit to the Southern market? I believe such is the condition to-day. It is not because there are no

longer good navigators and good boats, but it is owing to the wonderful development of new coal fields by railroads, their ability to put coal into the Southern market at all times and at all grades and prices, together with the Kanawa shipments. Let me read you extracts from testimony recently taken by the Government *re* The Monongahela River Navigation Company :

Mr. John F. Dravo's sworn testimony on behalf of United States Government, *re* Monongahela Navigation Company :

Mr. Griffith :

"Q. What, in your opinion, are the reasons for that condition of the Southern markets (meaning the losses to navigators during the past three years) and what is its probable effect on the Pittsburg coal trade to the market?

A. Well, the coal trade must quit ; it must quit if this condition of things exists, continues to exist. The condition of the market is brought about by several things. The first is, the shippers here, like men in other businesses, undertook to make up for the low prices of coal by taking out larger tows and doing a larger business, and in view of the frequent rises of 1896, they overdid the business ; they have overstocked the market ; there is coal enough now in the market for the next six months. A second reason is here manifest by the statements I have given as to the completion of the railroads (see tabulated statement of coal shipments to Louisville and Cincinnati). That is increasing all the time. West Virginia is making tremendous and unheard of efforts ; they are building railroads in every direction and opening up coal mines at all possible points and running into these markets. And, of course, that takes the place of the Pittsburg coal, and that has helped to overstock the market and to depress the prices."

Mr. Dravo, further on, remarks that on completion of the two locks and dams on the Kanawha : "Now, when they get their locks completed and have constant access to the

Ohio River, then they will scoop us off the earth. In the first place they make practically three trips to our one; that is, they can make two trips, absolutely two trips to our one; it is 267 miles below Pittsburg and 200 miles from Cincinnati; so they make two trips to our one, and save from five to six hundred dollars on the cost of transportation; but, then, they take larger tows, because they are below the most dangerous navigation on the Ohio River: and so, if you will add the larger tows to the two trips, it practically amounts to three trips to our one. And then, we have often to send out a helper. Now, there was a tow the other day lost two barges on the Bellaire bridge and yet the owner of that tow sent out a helper, clear down there, at a cost of $75 to $100 a day. They don't do that at Kanawha. And then, the Kanawha coal sells just as free and for as good prices as the Pittsburg coal, some of it higher. It is quoted in the Chicago market at twenty-five cents higher than Pittsburg coal," &c., &c.

"Q. Then, in your opinion as a coal man, would you state whether you think the competition of the Kanawha coal with the Pittsburg coal has yet reached its climax or its maximum?

A. Not by a good deal. I don't know what we will do when it gets full navigation out of the Ohio. I think we will have to quit."

NOTE.—There are two locks and dams at the mouth of the Kanawha not yet completed.

Portions of testimony given by Mr. I. N. Bunton.

"Q. What has been the condition of the market in down the river points as to competition within the last five years?

A. Well, to my sorrow, I regret to say that it has been very unfortunate.

Q. Has that competition been increasing and becoming more sharp year by year, or been decreasing?

A. It has been continuously increasing.

Q. From what source does that competition come?

A. Well, partially by river, but principally from railroad competition," &c.

Many other navigators testified, confirming the same conclusions.

The following shows how surely and rapidly the Pittsburg coal is being forced out of the markets just as the navigators testify. The condition down below Louisville is just the same:

COMPARATIVE STATEMENTS OF SHIPMENTS FROM PITTSBURG, KANAWHA AND BY ALL RAIL.

Location.	Year.	Pittsburg Boats.	Kanawha Boats.	Railroad.
Louisville,	1889	21,066,666	2,633,333	6,931,529
	1895	10,533,339	2,106,666*	13,779,781
Cincinnati,	1877	26,743,055	6,356,623	2,083,815
	1895	26,675,822	15,106,095	28,346,823

*65 runs short in 1895.

You see at a glance the "wonderful and unheard of strides" mentioned in Mr. Dravo's testimony that the railroads are making in the Southern market.

RIVER COAL TRADE.

ITS DECADENCE POINTED OUT BY A STUDENT OF WATER TRANSPORTATION.

To the Editor of the Commercial Gazette:

In a new country like the United States, with a territorial area reaching from ocean to ocean, as population and trade follows the "Star of empire" in its course westward, the consequent change of centers of trade create many perplexing commercial problems.

The shifting of such centers leaves many idle industrial plants, depreciating the value of costly investments and throwing multitudes of industrious workmen out of employment, entailing special hardships upon employer and employe. The transfer of the farming industry from Western Pennsylvania and other sections of the country to the fertile prairie lands of

the West has worked to the serious detriment of home farms. It is the old story of competition, stimulated by new and more favorable conditions, in contest with the old and less favorable surroundings. As a consequence of the development of the large and easily tilled farms of the West, with the facilities to supply the markets at lower rates, comes the depreciation of home farm investments and the non-compensation of farm toil; hence, general discontent among our farming population. The staid and contented farmer of other days has become an unreliable factor in political movements. Wheat and corn markets are overstocked, prices rule low, and the farmer of the older sections of the country finds his occupation gone. Heavy tax rates, without corresponding income, tends to bankruptcy of farm investments, and so comes the discontent which is disrupting old party lines.

The supremacy of Pittsburg as an iron center is periled by the new and formidable competition of the South. The favorable conditions found in Alabama for furnace and mill make it necessary for the iron master of the North to invest large capital to successfully compete with these late developments. The new Carnegie railway, to provide cheaper toll rates for mill supplies, grows out of southern competition. And so the battle goes on, as trade centers shift from point to point. Farm, mill and mine have to struggle for life, the contest of the old with the new demanding less home burdens, with increased facilities for production and shipment.

The river coal trade of this city is another illustration of the marvelous changes which have taken place in recent years. The time was when the Pittsburg river coal trade was king of the black diamond industry. The river shipper had exclusive possession of the river markets from Pittsburg to New Orleans and, during low water periods made money by advances in selling prices. But those days are gone. New factors have developed. Railroads have penetrated new territory of supply, and railroad trains run every day the year around and keep up

a continuous stock. In the Cincinnati market, formerly exclusively supplied by river with Pittsburg coal, the consumption of coal for the year 1896 amounted to 79,689,109 bushels. Of this amount Pittsburg shippers, with almost continuous navigation that year and with unlimited shipping facilities, only furnished 36,696,759 bushels, or less than one-half. At Louisville the same conditions exist. Formerly Pittsburg had undisputed possession of the market. The statistical report for the year 1895 (the latest at hand) tells the same story of decrease. The consumption for the year was 28,263,113 bushels. Pittsburg's share of this supply was only 10,500,000 bushels, a little more than one-third. At New Orleans rail shipments are supplanting the river trade; and so the battle of competition goes on, but goes against Pittsburg at every point.

While the Pittsburg river trade, in view of imposed disabilities, is declining, new and competent sources of supply are forging to the front. State Mine Inspector Hillhouse, of Alabama, furnishes the following coal statistics: Coal output for 1896, 150,935,767 bushels. Increase over 1895, 685,325 bushels. Coke, 129,487,000 bushels. Increase over 1895, 32,000,000 bushels. In view of these astounding figures, is it any wonder that Pittsburg shippers are alarmed, or that they demand exemption from corporation tax on navigation, or that they seek free improved rivers, on a par with shippers on the Warrior river of Alabama?

These shifting centers of trade and supplies impose great hardships upon Pittsburg shippers and their employes. In addition to increasing rail supplies, the constant increase of bridge piers renders navigation more costly and dangerous. The river competition of free Kanawha, one-half nearer the Cincinnati market, increases the strain, and it would seem as though the Pittsburg river trade is doomed. Unless relief comes from some source, the great towing steamers which crowd our wharves and give Pittsburg marine supremacy on

western waters, will have to seek other waters and the glory of the Ohio river will have departed.

That railroads are carrying a large portion of the coal output of the Monongahela valley is proven by the statistics of the Monongahela division of the Pennsylvania railroad. This single road carried in 1896 26,082,310 bushels, an increase in ten years of more than 16,000,000 bushels. If the statistics of the other railways carrying coal from the Monongahela valley were at hand, there can be no doubt that the output for 1896 would be over 50,000,000 bushels. Shippers find it more profitable to ship by rail than by river, with river drawbacks of toll tax, landing charges, bridge piers and detention of steamers at the locks. These are serious obstacles to overcome.

In the contest of the old with the new, all possible burdens and hinderances ought to be removed that the old may remain in the field of competition. All communities are interested in keeping alive every element of trade. A decaying commerce, manufacturing or mining industry, works against general prosperity of city and community. A dead limb on a tree is an evidence that death has commenced its work. A paralyzed human limb indicates that the tides of life are receding.

The decrease in river coal shipments indicates the coming end of that trade, unless arrested by the removal of some, at least, of the causes which conspire to cripple a commerce which in other years contributed so largely to the prosperity of the city. It is well to remember that with the loss of the river coal trade, the importance of the improvement of the Ohio river will lose much of its force and fail to command the western and southern support which it now receives.

JOHN F. DRAVO.

As is the case with the all rail coal shipments in the Southern market, the railroad freight rate to and from Pittsburg settles the question of her holding the balance of trade

and her prestige as a manufacturing center. The hauling of ore from the Lakes and the return loaded with finished materials and coal and coke make the Lake trade the most lucrative and unique in the country. The coal tonnage for the Pittsburg district previously read, bear in a most interesting manner on what may be depended as becoming more pronounced in the future. In 1895, 14,000,000 tons were hauled away by railroads and only 2,500,000 tons by river, less than any other one railroad except the B. & O. railroad, which was 2,000,000, yet greater than any other one railroad in the amount handled for local consumption, the amount being 1,538,000 tons, followed next by the P. R. R. at 1,200,000 tons, though carrying out of this district twice the tonnage of the combined down river fleets for the same year. Will the time ever come when the coal and coke in this vicinity will serve Pittsburg's best interests as a great commercial center to abandon the Southern coal trade to meet local consumption and Lake trade? These are big problems and so is Pittsburg's future. Statistics and the testimony of well-known river navigators and shippers in the Monongahela Navigation Company condemnation hearings, just read, fully justify the above conclusions. The railroads must grant lower freight rates and without the return haul to the lakes, this cannot be done successfully. With coal and coke it can be. What applies to the lake trade answers that of all others concerning Pittsburg.

Let us now examine the Dalzell Bill :

54TH CONGRESS,
2D SESSION.

H. R. 9866.

IN THE HOUSE OF REPRESENTATIVES.

JANUARY 7, 1897.

MR. DALZELL introduced the following bill; which was referred to the Committee on Interstate and Foreign Commerce and ordered to be printed.

A BILL

To authorize the construction of Bridges across the Ohio, Monongahela, Mississippi, Great Kanawha, Tennessee, Cumberland and Illinois rivers, and to prescribe the dimensions of the same.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress Assembled, That any persons or corporations, having lawful authority therefor, may hereafter erect bridges across the Ohio, Mississippi, Monongahela, Great Kanawha, Tennesee, Cumberland and Illinois rivers for railroad or other uses, upon compliance with the provisions and requirements of this Act.

Ohio River, 1,000 foot span.

SEC. 2. That every bridge hereafter erected across the Ohio River shall have its axis at right angles to the current at all stages, and all of its spans shall be through spans. Every such bridge shall have at least one channel span placed over that part of the river usually run by descending coal fleets, said channel span to give a clear waterway between the piers of one thousand feet, measured on the low-water line. Said channel span shall be at least forty feet above local highest water, measured to the

lowest part of the span, and shall be at least ninety feet above low water in bridges built above the mouth of the Big Sandy River, and at least one hundred and four feet above low water in bridges built below the mouth of the Big Sandy River, measured to the lowest part of the span.

Upper Mississippi, 500 foot span.

SEC. 3. That every bridge hereafter erected across the Mississippi River, between the mouth of the Missouri River and the city of St. Louis, shall have at least one channel span placed over that part of the river most used for navigation, said channel span to give a clear waterway between the piers of not less than five hundred feet, measured on the low water line, and clear head-room of not less than seventy-five feet, measured from high-water mark of eighteen hundred and forty-four with straight bottom chord; and that every bridge hereafter erected across the Mississippi River, at or below St. Louis, shall have at least one channel span placed over that part of the river most used for navigation, said channel span to give a clear waterway between the piers of not less than one thousand feet, measured on the low-water line, and clear head-room under all the spans of not less than seventy-five feet, measured at high-water mark at the point of the location of the bridge, except that hereafter bridges shall not be erected across the Mississippi River within the limits of the harbor of St. Louis in closer proximity to each other than two miles unless they be suspension bridges with no piers in the water at ordinary stages of the river.

Lower Mississippi, 1,000 foot span.

Monongahela, 800 foot span.

SEC. 4. That every bridge hereafter erected across the Monongahela River shall have at least one channel span placed over that part of the river usually run by descending coal fleets, said channel span to give a clear waterway between the piers of not less than eight hundred feet, measured at pool full in said river, and shall give a clear head-room of not less than fifty-four feet, measured from the water at pool full of the pool in which the bridge shall be located.

Kanawha, 500 foot span.

SEC. 5. That every bridge hereafter erected across the Great Kanawha River shall have at least one channel span placed over that part of the river usually run by descending coal fleets, said channel span to give a clear waterway between the piers of not less than five hundred feet, measured at pool full in said river, and shall give a clear head-room of not less than eighty-two feet, measured from the water at pool full of the pool in which the bridge shall be located.

Tennessee and Cumberland, 250 foot span.

SEC. 6. That every bridge hereafter erected across the Tennessee or Cumberland River shall have at least one channel span placed over that part of the river most used for navigation, said channel span to give a clear waterway between the piers of not less than 250 feet and a clear head-room under the entire span of not less than one hundred feet, measured from zero stage of water at the point of the location of the bridge.

Illinois, 250 foot clear draw span.

SEC. 7. That every bridge hereafter erected across the Illinois River shall have at least one draw span located over that part of the river most used for navigation, said draw span

to give a clear waterway between the piers of not less than two hundred and fifty feet; that said draw span shall be operated by steam, or other reliable power, and shall be opened promptly upon reasonable signal for the passage of boats, except when trains are passing over said span; but in no case shall unnecessary delay occur in opening said draw after passage of a train; and, also, in case the opening of a draw is delayed by reason of the passing of a train after the signal has been given from a boat ready to pass through, the draw shall be opened for the passage of such boat before another train is allowed to pass over the said span; nor shall there be any unnecessary delay in the passage of trains over the bridge.

Piers built parallel to river current.

SEC. 8. That the piers of all bridges constructed under the provisions of this Act shall be built parallel with the current at that stage of the river which is most important for navigation; and that no ripraps or other outside protection for imperfect foundation, which will lessen the required waterway, shall be permitted.

Public Notice in Newspapers.

SEC. 9. That any person, company, or corporation, authorized to construct a bridge across any river hereinbefore mentioned shall give notice by publication as follows: For bridges across the Tennessee or Cumberland River notice shall be given for one week by publication in a newspaper in the cities of Evansville, Nashville, Cairo, and St. Louis; for bridges across the Illinois River notice shall be given by publication for one week in a newspaper in Peoria and in two newspapers having

a wide circulation in St. Louis; for bridges across the Monongahela River notice shall be given by publication for one week in two newspapers having a wide circulation in the city of Pittsburg; for bridges across the Great Kanawha River notice shall be given by publication for one week in a newspaper in Charleston, West Virginia, and in two newspapers having a wide circulation in the cities of Pittsburg and Cincinnati; for bridges across the Ohio River notice shall be given by publication for one week in newspapers having a wide circulation, in not less than two newspapers in the cities of Pittsburg, Cincinnati, and Louisville, for bridges above the mouth of the Big Sandy River, and in the cities of Pittsburg, Cincinnati, Louisville, St. Louis, Memphis, and New Orleans for bridges below the mouth of the Big Sandy; for bridges across the Mississippi River notice shall be given by publication for one week in newspapers having a wide circulation, in not less than two newspapers in the cities of Pittsburg, Cincinnati, Louisville, St. Louis, Memphis, and New Orleans.

Plans, Maps, Drawings Required.

SEC. 10. That any person, company, or corporation, authorized to construct a bridge across any river hereinbefore mentioned shall submit to the Secretary of War, for his examination, a design and drawings of the bridge and piers, and a map of location, giving for the space of at least two miles above and one mile below the proposed location the topography of the banks of the river and the shore lines at high and low water. This map shall be accompanied by others, drawn on the scale of one

inch to two hundred feet, giving, for a space of one-half a mile above the line of the proposed bridge and a quarter of a mile below, an accurate representation of the bottom of the river, by contour lines two feet apart, determined by accurate soundings, and also showing over the entire width of this part of the river the force and direction of the currents at low water, at high water, and at least one intermediate stage, by triangulated observations on suitable floats. The maps shall also show the location of other bridges in the vicinity, and shall give such other information as the Secretary of War may require for a full and satisfactory understanding of the subject. Said maps and drawings shall be referred to a board of United States engineers for examination and report, which board shall personally examine the site of the proposed bridge, and shall hold a public session at some convenient point to hear all objections thereto, of which public session due notice and invitation to be present shall be given to all interested parties, and if said board of engineers reports that the site is unfavorable, the Secretary of War shall be authorized, on the recommendation of said board, to order such changes in the bridge or its piers or such guiding dikes or other auxiliary works as may be necessary, at the expense of the proprietors or managers of such bridge or piers and other works, for the security of navigation; and the proposed bridge shall only be a legal structure when built as approved by the Secretary of War.

Lights on Bridges.

SEC. 11. That all parties owning, occupying, or operating bridges over any of the rivers hereinbefore mentioned shall maintain at their own expense from sunset to sunrise throughout the year, such lights on their bridges as may be required by the Light-House Board for the security of navigation, said lights in number, location and power to be as the Light-House Board may prescribe; and all persons owning, occupying, or operating a bridge over any of said rivers shall in any event maintain all lights on their bridges that may be necessary for the security of navigation.

Mails, Post Route Troops, Etc., and Charges.

SEC. 12. That any bridge constructed under this Act, and according to its limitations, shall be a legal structure and shall be recognized and known as a post route, upon which, also, no higher charge shall be made for the transmission over the same of the mails, the troops, and the munitions of war of the United States than the rate per mile paid for the transportation over the railroads or public highways leading to said bridge; and the United States shall have the right of way for postal telegraph purposes across any such bridge; and in case of any litigation arising from any obstruction or alleged obstruction, to the navigation of said river created by the construction of a bridge under this Act the cause or question arising may be tried before the circuit court of the United States in and for any district in whose jurisdiction any portion of said obstruction or bridge may be.

Rules for Erection.

SEC. 13. That during original construction of any bridge built under the provisions of this Act, or in carrying out any authorized change or repairs of said bridge, a navigable channel, sufficient to accommodated the commerce using the river at the point of the location of the bridge, shall be preserved at all times, and such lights and buoys shall be kept on all cofferdams, piles, and so forth, as may be necessary for the security of navigation; and all false work, piles, and so forth, used in the construction or repair of the channel span of said bridge shall be removed within ten days after completion or repair of said channel span.

Good Faith Clauses.

SEC. 14. That whenever the Secretary of War has good reason to believe that any of the provisions of sections eight and thirteen of this Act have not been complied with by the company or persons owning, controlling, or operating the bridge authorized under its provisions, it shall be the duty of the Secretary of War, on satisfactory proof thereof, to require the said company or persons to comply with the provisions of said sections, and on failure of said company or persons to comply with said requirements within a reasonable time, the Secretary of War shall proceed to cause the necessary work, in the form of additions, alterations, repairs, or removal of obstructions to be made at the expense of the United States, and shall refer the matter, without delay, to the Attorney General of the United States, whose duty it shall be to institute, in the name of the United States, proceedings in the circuit court of the United States in and for the district in which

any portion of said obstruction or bridge may be, for the recovery of such expense, and all moneys accruing from such proceedings shall be covered into the Treasury of the United States.

Time Limit.

SEC. 15. That any permission granted by the Secretary of War under the provisions of this Act for the construction of a bridge across any river hereinbefore mentioned, shall be null and void if said construction be not actually commenced within one year and completed within three years from the date of said permission.

Rights are Reserved for Amendments.

SEC. 16. That the right to alter or amend this Act, so as to prevent or remove all material obstructions to the navigation of said rivers by the future construction of bridges, is hereby expressly reserved without any liability of the Government for damages on account of the alteration or amendment of this Act, or on account of the prevention or requiring the removal of any such obstruction; and if any change be made in the plan of construction of any bridge under this Act during the progress of the work thereon or before the completion of such bridge, such change shall be subject to the approval of the Secretary of War, and any change in the construction or any alteration of any such bridge that may be directed at any time by Congress shall be made at the cost and expense of the owners thereof.

Power Supreme.

SEC. 17. That all laws and parts of laws that may be in conflict with this Act are hereby repealed.

The members of the Pittsburg Coal Exchange act wisely when they propose to do away with the necessity of getting a special act of Congress whenever it is proposed to bridge the Monongahela; it is better by far to leave the whole matter to the War Department, as is now done on the Allegheny River, and under the present special laws on the Ohio River. It will eliminate much of the unpleasant friction of the past. I shall dismiss the argument of the bill for an 800-foot clear span over the Monongahela River by saying that there are hundreds of places between Pittsburg and Brownsville, 55 miles, where the river isn't 800 feet wide. There are no fleets where there are locks and dams. It is vastly different with the Ohio River, when we realize that one-half its entire tonnage is furnished from this district, principally from the Monongahela alone. The shippers interested in these shipments must receive fair play and simple justice; though this does not entitle them to ask Congress to pass bills that would kill legitimate railroad enterprises desiring to bridge the Ohio River, and yet would be of little or no benefit to navigators. To prove this, I respectfully call your attention to a few surveys and sketches I have personally made for the occasion, between Pittsburg and Beaver, March 15th, when the river at Davis Island Dam marked 11′ 6″ at 7.30 A. M. You will readily see that the condition of the water was favorable to navigation, and any piers not within the navigable channel on a rise of this kind could hardly be considered harmful to the river interests even at a 20 feet rise. The points selected have been noted for the losses of the past few years and are where the longest spans would be demanded.

That you may have clearly in mind the magnitude of a 1,000 foot clear span, imagine a clear span extending from Fifth avenue to Water street, or from Water street to the P. & L. E. R. R. tracks.

1. The first is opposite Haysville, on the Pittsburg, Ft. Wayne & Chicago Railroad, and just below Neville Island.

From the island above the dike to the shore on the other side, a clear waterway of 785 feet was found, and by placing one pier just inside of the edge of the water on the bank the other pier for a 1,000 foot clear span extended clear over the island; it was the same for the dike. Eight hundred feet would clear both points. Why, then, a 1,000-foot span?

2. The second location was chosen at Dead Man's Island, where a reference to the sketch shows exactly the same condition—an 800-foot clear span would clear everything at a 11-foot, 6-inch stage of water, and a 1,000-foot span lands one pier in the bank channel and the other out of the water on the other side.

3. The third point selected was at Logstown Dam, revealing the same condition of things as farther up the river.

The last sketches are of the Beaver Bridge, and vicinity, one of the worst points in the upper river navigation.

All of the above locations have been chosen on account of being difficult and dangerous, and except Logstown Dam, made and fashioned by Nature and not man. If these islands existed so many years it is reasonable to assume they will continue after the river is locked and dammed to Beaver. I didn't dig up ideal cases to illustrate the meaning of the Dalzell Bill.

Last year I made a detailed plan and careful estimate of a proposed double track railroad bridge at Beaver, extending the same piers far enough up-river to admit of placing the new structure. This bridge (Fig. 1) was to be built on the best

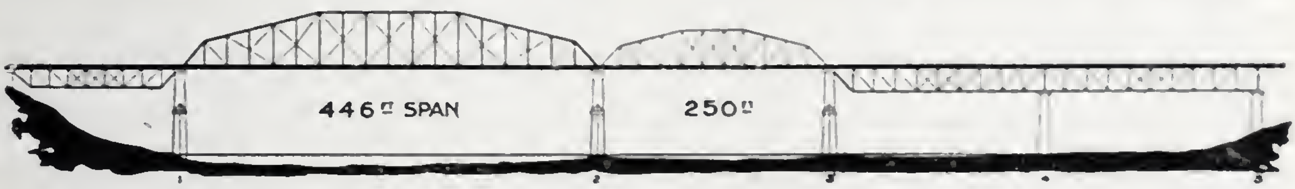


Fig. 1.

modern plans, for which I estimated it would cost complete $428,000. I do not say that this should be done; in fact, it should not be, as the channel is too narrow now for so bad a place in the Ohio River.

That we may the better see the far-reaching effect of the Dalzell Bill, I now call your attention to a suspension bridge (Fig. 2) I have designed, figured out in detail and estimated

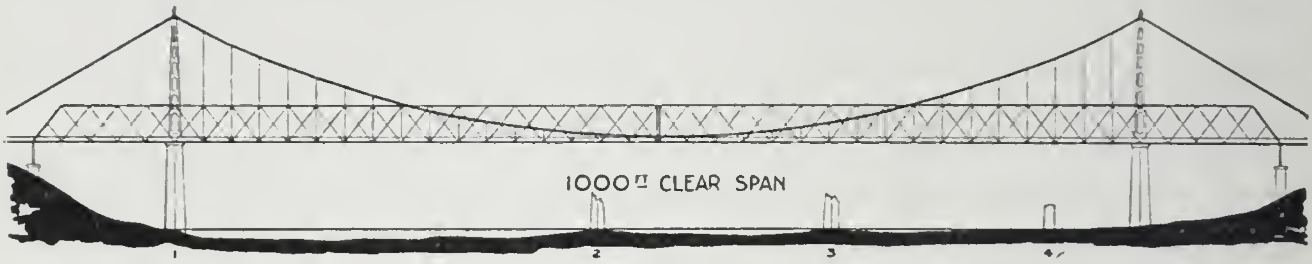


Fig. 2.

complete for the same location, but with a 1,000-foot clear span, throwing, as it does, the Beaver pier clear out of the river, away back behind the bar at the mouth of the Big Beaver River, where no boat ever gets or could float to on any stage. Is there any sense or justice in demanding such construction? A close estimate of quantities of the sub and superstructure of this design, based on prices contracted for to-day, puts the cost at $1,300,-000 for a suspension bridge, and twice as much for a fixed span of same length with approaches the same as for the suspension bridge. There are many points just here I would like to take up and discuss, but I am taking too much time as it is and only ask your indulgence a few minutes longer.

SUMMATION.

It has been my pleasure and duty to fully state both sides of this matter in an entirely impartial manner. Every point surveyed has been presented, there was no selecting of ideal cases and in not a single point was the river from shore to the island or dike, as the case may be, over 800 feet, 200 feet less than the Dalzell Bill demands. Few tows pass these points with over six boats abreast, say at 30 feet wide each would be 180 feet, yet the river men say they must have a clear span not less than 1,000 feet, the width of their tow greater than the channel, at an 11 foot stage, from land to land, at Brunot's Island, Neville Island, Deadman's Island, etc. If so many places can be found in twenty-five miles, what would be the volume of information between here and Cairo, nearly

1,000 miles? The Dalzell Bill has been proven wrong in every location mentioned, and if passed as presented would be a cruel instrument, ignorantly used, aimed at the heart of this country's greatest institution, the railroads, the great commercial carriers which the leading shippers by river all unite in saying, in the Government proceedings *re* The Monongahela Navigation Condemnation, are crowding them out of the markets from Cincinnati to the Gulf of Mexico.

Has the importance of the Monongahela River become so great that in the future all railroad bridges must have a span greater than any yet built in the United States of America? Has the Ohio River a future so promising that nothing less than 1,000-foot clear channel spans shall be allowed, over 200 feet more than any railroad bridge built in this country? I believe more coal is carried over nearly every railroad bridge below Pittsburg than the combined fleets of coal carried under them.

Would it be wise to enact laws that would abolish future railroad construction East and West, crossing the Ohio River, simply to satisfy the desire of a river trade admittedly fast and surely dying? Too much care, however, cannot be exercised in the placing of river piers.

I am inclined to believe that the river men have been led to think that because the Liverpool and Rochester suspension bridges had channel spans of 700 and 800 feet, respectively, that all bridges could be just as well built hereafter of 1,000 feet clear span and only the asking would be necessary. If this be true, they have made a sad mistake, as both these structures are light highway bridges. There would be a vast difference in the structures and their costs were they replaced by double track railroad bridges. The navigators say it is only a matter of cost, and they propose to make the railroads meet it hereafter. Does their own sworn testimony entitle them to exact conditions that will kill legitimate enterprises? They are dying too fast themselves, and in too unhealthy a state to talk cures to others.

Let our Government engineers do that. Let us have laws passed that will make our Government engineers sole arbitrators. I most sincerely hope and trust the Government will make the Monongahela River free. It will grant a longer time for the river interests South to adjust themselves to the loss of the Southern market, which is surely and rapidly disappearing, and before many years large down-river fleets of coal will be a thing of the past. It has been hinted that the engineers have no business to interfere with the navigation questions governing the rivers. The engineers handle enormous sums of money expended in a multitude of ways and callings, and my main object in joining this society was that I might sometime assist to make this society a prominent factor in promoting and guarding Pittsburg's welfare. I claim it is as much our duty as it is that of the Chamber of Commerce or any other body to take an active interest in everything social, political and financial pertaining to the best interests of those about us, especially Pittsburg's commercial advancement.

I trust enough has been said to clearly show and thoroughly convince you that the Dalzell Bill is a monstrous injustice.

PRESIDENT. You have heard the reading of the paper and the meeting is now open for discussion. I understand that some of the river men have been invited to attend this meeting, and if any are here they will be heard.

MR. W. G. WILKINS. Was not Mr Dravo invited to be present at this meeting?

MR. E. K. MORSE. Mr. Dravo is out of the city. I sent invitations to the Assistant Secretary and he was to distribute them to the river interests. He asked me if he could get a copy of the proceedings of this evening. I told him that he could procure them after they were printed.

PRESIDENT. If there are no river men here, it seems as if we were going to have everything our own way.

Mr. G. Kaufman. I do not know that I have anything of interest to add to what Mr. Morse has said. In discussing a paper read by Mr. Roberts before this Society, December, 1893, I made some vague assertions concerning the decadence of the coal trade. These statements have been to-night fully corroborated by Mr. Morse, who, of course, made a much fuller and more complete investigation than I did. I am very much against the regulating of the building of bridges over the Ohio River, or over any river, to accommodate any particular traffic, especially a traffic like the coal trade down the Ohio River as it is carried on at the present time. The amount of coal shipped down the Ohio River in 1895, was, according to the paper read to-night, about 80,000,000 bushels. The value of that on the boats is about four cents a bushel, or $3,200,000, equal to about the trade of Jos. Horne & Co., of this city, or to the business done by three or four smaller firms. If Jos. Horne & Co. would ask Congress to construct a free railroad for them so that they could compete with merchants in St. Louis or any other place; or if they would ask for legislation which would interfere with the business of other firms doing many times the business they did, they would be laughed at. That is about the way I look upon the effort that is being made by the coal interests. They are trying to benefit themselves at the expense of other and more important interests. It is all right, in my opinion, to build dams, and improve our water-ways, but such legislation as that proposed in the Dalzell Bill is preposterous. If the Ohio River had been improved years ago with the permanent dams at small cost, such as those in the Monongahela, it would have been much better for the Ohio River Valley. The progress of that section of the country has been kept back much by the adoption of the Chanoine system of movable dams, which are so expensive to construct that it will be years before the Ohio will be completely improved. For this reason, in my opinion, Col. Merrill erred in advising the adoption of this system. He

attached too much importance to the transportation of coal by the tremendous fleets as now carried on. With permanent dams the coal men would very soon have accommodated themselves to that condition of affairs.

As far as that portion of the bill is concerned which deals with the question of maps, I think it is all right. There should be an accurate map of the river, extending at least two miles above the proposed site, and one mile below it. There should also be a full understanding of the bottom of the river, and of the currents, etc.

PRESIDENT. Do you believe it is necessary to have a contour map made from soundings taken only two feet apart?

MR. G. KAUFMAN. Yes, sir, I do think contours should be given every two feet apart vertically. An accurate knowledge of these things helps greatly.

I am gratified to know that two bridges in which I was interested, one at Wheeling and one at Cincinnati, have not been the cause of any accidents as shown by Mr. Morse's statistics. Before these bridges were constructed, an absolute understanding was had of the river bottom. Although not required by law, we also took triangulated observations of coal fleets passing the sites, and platted their courses.

The bridges were located with great care; the channel spans of both bridges are each five hundred feet in width and are amply sufficient.

Mr. President, I think this Society and this community are greatly indebted to Mr. Morse for his paper, which is complete in every particular. He must have gone to a great deal of expense, and devoted a large amount of time in its preparation. I think, at the proper time, that a motion should be made conveying the thanks of the Society to Mr. Morse. I also think that the paper, or a full report of it, should be sent to Mr. Dalzell, and to the Congressional committee which has this matter in charge.

MR. GEO. S. DAVISON. I am opposed to this Society

taking up any matter of public improvements, at any time, and in any way, that would appear to be in the interest of any class or combination of business, or anything else.

The Dalzell Bill itself amounts to a practical prohibition against certain lines of business, and that of itself is wrong. The bill seems to be aimed directly at the railroad interests; but if there was a bill introduced into Congress which would have a similar effect upon the coal trade, I would be just as quick to get up on this floor and make a plea against it. It is the principle that is at stake, but in striking a blow for the principle, we do not need to ally ourselves with any special business. I think we all agree upon that. We all want to see fair play and that is what this meeting was called for.

Mr. E. K. Morse. That is what I said, all we want is fair play, that is, justice.

Mr. Davison. I was very sorry to hear some parts of Mr. Morse's paper. That is, that an old established industry, the river coal business, is declining; but I am equally opposed to Congress affording such protection to this declining industry as to practically prohibit the building of bridges across the Monongahela and Ohio rivers. Mr. Morse seems to place particular stress on the building of railroad bridges. Of course I know, in a general way, he meant *all* bridges, because all the bridges that are likely to be built are not necessarily railroad bridges. There are many that will be built for other purposes. We who live in Pittsburg know the advantage of having many bridges across the Monongahela and Allegheny rivers. These bridges are built for the purpose of accommodating the population along the rivers. People have as much right to walk across a bridge as to row across the river in a boat, and they should not be prohibited from doing this as long as capital stands ready to erect the structures that will enable people living on opposite banks of a river to conduct their commercial relations with greater facility. It is not right that the building of bridges should be prohibited.

I saw a newspaper article in which it was stated that the engineers could not build a one thousand foot span bridge under the prevailing conditions; that an eight hundred foot span was about the limit. That is not true. It can be done. That is not the point upon which the engineers object to the bill. It is, that such a long span would so increase the cost as to practically prohibit the building of any bridge whatsoever, and it looks to me as if that bill was framed with this very purpose in view. I was very much surprised to see such evident discrimination in the bill as it was read by Mr. Morse this evening. There is no doubt but that the Monongahela and Ohio rivers have been greatly discriminated against, and it seems very evident to me that the power behind that bill must be in this very neighborhood. I do not know this, but it looks that way.

There are a few absurdities in the bill. I agree with Mr. Kaufman that everything should be done by the engineers to make the plans for a proposed bridge complete in showing the situation and proposed conditions. But as regards that part of the bill which states that the axis of the bridge shall be at right angles to the current at all stages, I very decidedly object to that.

PRESIDENT. Why do you object to this? They are built at right angles now.

MR. DAVISON. I object because it is absurd to think of getting every bridge at right angles with the current of the river at all stages. I object also to that portion of the bill which provides the height of the clearance, and another portion where it stipulates that the spans shall be *all through spans*. I do not see why they should limit the character of the span after the required height has been given. I suppose if the bill were gone through carefully, that other absurdities might be found.

I might say that shortly after I read of this bill being introduced into Congress, I thought of formulating a set of

resolutions to be submitted at the last meeting of this Society, but hearing that Mr. Morse had the matter in hand, I did not do so. I would suggest, if the discussion warrant, that in place of a set of resolutions, the President appoint a committee of this Society, who shall at once take up this Dalzell Bill, examine it carefully, collect proper data, and in a fair and impartial manner go through the subject, and at their own expense go to Washington, appear there at the proper time, before the committee having this matter in charge, and give a full exposition of the absurdities and discriminations which appear in the bill. I would not want the committee to go to Washington to attempt to knock out this bill, merely because there are a few objectional features in it. Let the good features go, but in a fair and reasonable manner show up the unreasonableness of the bill as it stands, and show what it ought to be I think the suggestion made by Mr. Morse, that every bridge should have a special hearing, and the questions be decided by the United States Engineers who have no interest in the matter, save to have a proper structure, of proper dimensions, built at a suitable point, is an eminently proper one.

Mr. W. G. Wilkins. The bill is practically prohibitory as it now reads. It is entirely and completely one-sided. I do not think that coal men or river men should expect favorable action on this bill, or to get it through by snap judgment. In all fairness, the river men should be heard ; in all fairness the other side should be heard, too. With the proper modifications, this bill would cease to be prohibitory, and might be a good thing. I think every proposed bridge should be considered on its own merits, subject only to the particular conditions prevailing at the locality where it is to be erected As it is now, whenever a bridge is to be erected, the plans are prepared by the engineer ; after they are prepared both sides have a hearing, and the Chief of Engineers decides how the bridge is to be built. This is fair to both sides.

I think it eminently proper for a committee of this organization to be appointed and authorized by the Society to go to Washington when the bill is before the committee and present the objections to certain features of the bill, and endeavor to have it modified along these lines.

PRESIDENT. Do you think there is any member of this Society who is personally sufficiently interested in this matter to go, at his own personal expense, to Washington to lobby against this bill? And if they go at their own expense and without the authority of the Engineers' Society, they certainly would lose some of their influence. I do not approve of introducing another bill to run counter to this one. You know what that means in a legislature, to have two bills running counter to each other. In my opinion it would be better to formulate a just and true criticism of the bill as it stands, and send it to our representatives.

MR. G. S. DAVISON. I think I was misunderstood, I did not mean to suggest that another bill should be drafted and presented to Congress. I think the present bill could be modified so as to be perfectly satisfactory.

I would say that I know a gentleman who is going to the seat of war to-morrow night, who will be quite likely to run across our representatives from this district while he is in Washington.

I would suggest, if it meets with the approval of the members of this Society, that this gentlemen be the bearer of any resolutions or criticisms which we may wish to offer, and they could be presented as coming from the Engineers' Society of Western Pennsylvania. They could be presented to our representatives and would be read at the proper time before the committee having the matter in charge.

MR. EDWIN F. WENDT. Mr. Chairman, it seems to me that the so-called Dalzell bridge bill is unreasonable, because it requires that all future bridges over several rivers, including the Ohio and Monongahela, shall have channel spans of certain

definite lengths measured between the piers at low water mark, irrespective of the location of the bridge, width of the river, the topography of the country or local requirements. The bill would require no longer spans in the Pittsburg Harbor than at a point near the Headwaters of the Monongahela River; no greater spans at Cincinnati and Louisville than at Neville Island. In short, the bill is rigid in its requirements and makes no exceptions in favor of bridges that may be built where Nature has designed a channel 300 or 400 feet less than is demanded by the proposed enactment.

In the year 1891 I made an investigation to determine what width of water-way was required to accommodate the Ohio River; cross sections of the river valley were taken at Steubenville, Alikamia, Smith's Ferry, and Beaver which show generally that the total width of the river at a good boating stage is 1,000 feet and that during very high water the width is increased by only a few hundred feet on account of the bluffs on either side of the river. As the channel at these points is only about 500 feet wide it would seem entirely unnecessary that bridges should have 1,000 ft. spans which would practically cover the whole width of the river. Consider for a moment the requirement for bridges over the Monongahela River. Between Pittsburg and Braddock the Government Engineers have established Harbor lines which are from 700 to 900 feet, or an average of 800 feet apart.

This represents the width of the river at a 20 foot stage, and when the banks take their slope of 1 on 3 the total width of the river at a 6 foot stage will be 716 feet. At Homestead the width will be only 616 feet, as the Harbor lines are only 700 feet apart at some points. In view of this fact, is it reasonable to require 800 foot bridge spans?

It seems to me that it is our duty as civil engineers to oppose this bill on the ground that its requirements are unreasonable and unnecessary, and detrimental to the commercial interests of the country. We should be prepared to show

that the topography of the river and surrounding valley is such that the long spans mentioned are grossly unreasonable, and that their cost would be so great as to prohibit their erection.

In my judgment the bill should be amended by eliminating its absurdities (such as a requirement that all spans should be through), by extending its provisions, if possible, over all the navigable waters of the United States, and by vesting in the Secretary of War the authority to decide all matters pertaining to the length of the spans, axis of bridge with reference to the direction of the current, necessity of deck or through spans, and over-head clearance. It would seem from the third section of the River and Harbor Act, approved July 13, 1892, that such authority is already vested in the Secretary of War; and Attorney General Olney said that "Congress by express statute has given to the Secretary of War exclusive jurisdiction over the subject." Circuit Court Judge Goff has given an opinion bearing on this subject, in which he said:

"By section VII. of an act approved September 19, 1890, it is made unlawful to hereafter build in the navigable waters of the United States any structure of any kind in such manner as will obstruct or impair navigation without the permission of the Secretary of War. The evident intention of Congress was to take exclusive charge of such matters in the future for the United States, and to place them under the charge of the Secretary of War, leaving it to his discretion to authorize or prohibit the building of the structure and creation of the impairment of navigation, thus rendering it unnecessary to apply to Congress for permission or special legislation in particular cases, as had frequently been done heretofore."

Congress has certainly acted wisely in placing such wide discretion in the Secretary of War, and we may feel sure that his Engineer Corps will carefully guard the interests of the coal merchants as well as those of the railroads in the construction of bridges over navigable waters.

Mr. President, it seems to me that this is a proper subject

for discussion in our Society, and I will therefore favor a motion to appoint a committee to go to Washington to endeavor to have the so-called Dalzell Bridge Bill amended in accordance with the best judgment of the members of said committee.

Mr. Kaufman. Under the present laws, all bridges are constructed under the control of Government Engineers. Even under the provisions of a special act controlling bridge building on the Ohio River, the War Department reserves the privilege of altering the proposed spans of any project, if found necessary. In the case of one bridge with which I was connected, they required an 850 foot span. We had to submit, and the decision killed the project.

Mr. Davison. The *Engineering News* may be right; I think that they are wrong. The rivers of the United States are under the jurisdiction of the United States Government. A corporation wishing to build a bridge in the state of Pennsylvania, must first obtain the right, charter right, from the state of Pennsylvania, but even when that is obtained it does not give them the right to build their bridge; they must get the permission from the United States Government, and, perhaps, that is as it should be: but the question of *how* the streams shall be crossed is properly under the charge of the War Department. The War Department represents the Government and simply protects its interests, but I do not see why any one department of the Government should say that a corporation should, or should not, build a certain bridge; but the War Department should have facilities for knowing *how* it should be done. It is perfectly proper that this Department should say *how* it should be done.

Mr. Kaufman. I move that the thanks of this society be extended to Mr. Morse for the very able paper which he has read before us this evening.

Motion was seconded and carried.

After considerable discussion the following motion was made by Mr. Wilkins, and was duly seconded and carried:

Resolved, That the President appoint a Committee of five to appear before the Congressional Committee of Inter-State and Foreign Commerce at Washington, at the proper time, and endeavor either to defeat H. R. Bill 9866, or to have it so modified as to be a subject for decision by the War Department, and to have each and every case considered on its own merits.

The following committee was appointed :

E. K. Morse, Chairman.
Thomas H. Johnson,
Gustave Kaufman,
Geo. S. Davison,
W. T. Manning,
Emil Swensson, ex-officio.

A preamble and resolutions were then read by Mr. Kaufman ; but after a spirited debate it was decided that as the Society was there assembled at a special meeting, no other business could be legally transacted, and a consideration of the resolution was postponed until the next regular meeting.

Meeting then adjourned.

REGULAR MEETING.

The regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Society's House, 410 Penn Avenue, Pittsburg, Pa., Tuesday evening, April 20, 1897. The meeting was called to order at 8:20 P. M., by the President, Mr. Emil Swensson. Forty members and visitors were present.

The minutes of the last regular meeting, and of the special meeting of March 31st, were read and approved.

The Secretary then read a letter from Congressman Dalzell, in answer to the Society's communication *re* H. R. Bill 9866, in which the latter stated that the bill was not original with him, but had been sent him by the river men; that it would not be introduced until the next session of Congress, and that he would then be very glad to have the views of the Society with respect to the expediency of its passage.

The Secretary then announced the names of E. L. McGary and James R. Moore, as applicants for membership, passed by the Board and to be balloted upon at the next regular meeting.

The following names were balloted upon, and the gentlemen elected to membership in the Society by twenty-seven votes, the tellers being Messrs. Wendt and White: Eugene Friedlaender, Francis Hodgkinson, James S. Mack, Charles O. Rogers, James Todd.

Mr. Davison moved that the order of business be suspended so far as unfinished business is concerned until after the reading and discussion of papers.

Motion was seconded and carried.

The Committee on the death of Mr. Stevenson presented a memorial, and it was voted that this be spread upon the records of the Society.

For the Committee on Power, Mr. Fisher stated that on account of sickness and delays of various kinds, the Committee on Power had but little to report; that they have submitted a

list of questions to manufacturers and to the members of this Society, and hoped to be able to report something definite in the near future; that Mr. Stilwell, though he had left the city, had been retained on the committee, and it was expected that he would send some valuable data from Buffalo.

It was explained that the list of questions put was rather long in order to secure reliable results, and the assistance of the members was asked.

Mr. Davison asked if the committee had set any date or limit in which these circular questions must be answered.

Mr. Fisher said that with the approval of the Society the last of September would be set down as the limit.

The resolution presented at the last special meeting by Mr. Kaufman, was then read by the Secretary, as follows:

"At a meeting of the Engineers' Society of Western Pennsylvania, held April 28th, 1896, the following resolutions were offered and acted upon affirmatively by the Society:

'WHEREAS, In the proposed charter for cities of the second class it is provided that the Director of the Department of Public Works shall be elected by a direct vote at the city election, and

WHEREAS, The said charter also provides that the salary of the said Director of the Department of Public Works shall be four thousand ($4,000) dollars per annum, therefore be it

Resolved, That it is the opinion of the Engineers' Society of Western Pennsylvania that the Director of the Department of Public Works shall be an Engineer of established professional and administrative ability, and that it is the opinion of the Society that it will be impossible to obtain such a Director by direct vote of the people, and it is further

Resolved, That the Society does not believe that an Engineer, with the ability to design and supervise in a proper manner work of such magnitude as required by the City of Pittsburg, can be secured for the salary proposed, and that same salary is entirely inadequate for the services required.'

Since the adoption of these resolutions there has been a decided movement inaugurated towards changing the charter of the City of Pittsburg, and at the present time, the Legislature of the State, has under consideration some four or five proposed charters.

An examination of these show that the method of the appointment of the Director of the Department of Public Works is the same in all of the charters, and that is, by the Mayor. However, not one, in any shape or form, attempts to specify any qualifications that should be possessed by the said Director.

In order that the Society may accommodate itself to the existing conditions and that the interests of the City of Pittsburg may be conserved and properly protected in this most important office, the following resolutions are submitted :

Whereas, In a set of resolutions, passed April 28th, 1896, the Engineers' Society of Western Pennsylvania expressed its opinion that the Director of Public Works of the City of Pittsburg should be an Engineer of established professional and administrative ability and that it is improbable that an Engineer, with the ability to design and supervise in a proper manner work of such magnitude as required by the City of Pittsburg, can be secured for the salary proposed, and

Whereas, The knowledge gained by the experience of other municipalities in the United States, such as Boston, St. Louis and New York, indicates that it is fully as necessary that the head of the Public Works Department should be an Engineer as that the head of the Legal Department should be an Attorney-at-Law, and

Whereas, The experience of large and successful corporations throughout the United States, such as the Pennsylvania Railroad, is that it is possible and very advantageous to obtain executive officers who are trained and experienced Engineers. Now therefore be it

Resolved, That it is in the best interests of the City of Pittsburg that a clause limiting the selection of the said Director only to such as have the ability and experience as above mentioned, be inserted in the various charters proposed.

Resolved, That the salary of the Chief of the Department of Public Works should be equal to the salaries paid by Boston and St. Louis and other cities whose engineering work is of equal magnitude.

Resolved, That the Secretary of the Society be instructed to send a copy of these resolutions to each of the proposers of the various charters, to the Chamber of Commerce Committee, and also to the Chairman of the Legislative Committee having this matter in charge."

(In the resolution as at first presented, the sum of $10,000 was named as a suitable salary, but after some discussion, the resolution was amended so as to read as above.)

Mr. Bole then made a motion which, after some discussion as to number on committee and the payment of expenses, was finally put as follows:

"That a committee of three be appointed, one member of which shall be Mr. Davison, the second shall be Mr. Kaufman, the third to be appointed by the Chair, to appear before the legislative committee having the new charter for Pittsburg in charge, to present before them the views of the Society in regard to the matter."

This motion was seconded and carried.

The President appointed Mr. Shellenberger as the third member of the committee.

The paper of the evening, "The Transmission of Power by Compressed Air," by Mr. Hirsch, was then read by the author. (For this paper and the subsequent discussion of the papers of Messrs. Stewart, Wilkins and Hirsch, see pages 183 to 214 of the proceedings.

Mr. Davison. I move that the Society adjourn and go into a committee of the whole to continue the discussion of the

new constitution. I do this for the reason that there are many things to consider, and we shall probably get through them quicker if we discuss some of them each night. If this motion is carried it will not be necessary to discuss the entire constitution this evening but we could at least dispose of a portion of it.

Motion not seconded.

The Society then adjourned.

REGINALD A. FESSENDEN,
Secretary.

MEETING OF THE CHEMICAL SECTION.

The regular monthly meeting of the Chemical Section of Engineers' Society of Western Pennsylvania, was held in the lecture room of the Society's house, 410 Penn Avenue, April 22d, 1897. Chairman, W. E. Garrigues. Eight members were present.

Professor F. C. Phillips read a letter from Professor Edward Hart in regard to the reprints of the Methods collected by the Section.

On the motion of A. G. McKenna, it was resolved that the original committee on the collection of Methods should have included in the reprints any appropriate papers on Methods which have been read before the Society.

The Secretary read a communication from Mr. F. H. Williams, in regard to the "Analysis of Blast Furnace Cinders."

On the motion of Mr. Wilkins, the communication was ordered to be printed in the proceedings.

Mr. W. E. Garrigues then read a paper on "Methods of Determining Glycerol."

The paper was discussed by Messrs. Phillips, Johnson, McKenna and others.

The Section adjourned at 10.45.

Alexander G. McKenna,
Secretary C. S.

ANALYTICAL NOTES.

FRED. H. WILLIAMS, WHEELING, W. VA.

The recent paper by Mr. J. M. Camp on Blast Furnace Cinders and their Analysis, has suggested the offering of the following note as a further contribution to the subject.

BLAST FURNACE CINDER.

The estimation of *silica*, *alumina*, *lime* and *magnesia* for technical purposes is made by Textor's method (The Journal

of Analytical and Applied Chemistry, Vol. VII., No. 5, May, 1893) with a few variations, which are incorporated in the following abbreviated description:

The pulverized sample of cinder is freed from metallic iron with the magnet.

For *silica* and *alumina*, 0.500 grams are weighed into a 4¾ inch evaporating dish.

For *lime* and *magnesia*, 1.325 grams are weighed into a No. 3 beaker.

Into the evaporating dish for SiO_2 and Al_2O_3 pour 25 c.c. hot water and while stirring add 10 c.c. HCl. (1.10 sp. gr.). Add a few drops of nitric acid, cover and evaporate rapidly to hard dryness, the latter part of the operation being conducted on sand bath. Cool, add 15 c.c. HCl. (1.20 sp. gr.), boil two or three minutes, add 25 c.c. hot water, bring to a boil, filter, wash by decantation four or five times with hot water. Transfer filtrate and washings to a No. 3 beaker, place over burner to boil and precipitate alumina and iron oxide with usual precautions, the result being reported as alumina unless an abnormal amount of iron is present, in which case iron is separately determined in the cinder and the proper corrections made. While the alumina solution is heating the SiO_2 is completely transferred from the dish to the filter. When this is done it will have been sufficiently washed.

While the solution for SiO_2 and Al_2O_3 is evaporating, the determination of lime and magnesia is pushed forward.

Pour 25 c.c. of hot water into the beaker. The contents of beaker are given a rotary motion while adding 20 c.c. HCl. (1.10 sp. gr.). Boil, add 15 c.c. HCl (1.20 sp. gr.) and a few drops of nitric acid. Pour the solution into a 530 c.c. flask and dilute to about 350 c.c., add 27 c.c. ammonium hydrate (0.90 sp. gr.) in four or five separate portions, shaking flask after each addition. Add water to the mark, mix and pour into a No. 5 beaker. In three or four minutes the precipitated SiO_2 and Al_2O_3 will subside sufficiently. Decant into a

graduated flask 200 c.c. of the clear solution (representing 0.500 grams of cinder) for the determination of *lime* and *magnesia*. A few flakes of the precipitate passing over are of no consequence as they are subsequently retained with calcium oxalate on the filter, and do not interfere with the volumetric estimation of lime. Pour the 200 c.c. into a No. 3 beaker, boil, add 20 c.c. saturated solution of ammonium oxalate, *dropping* the reagent rapidly from a pipette with vigorous stirring. In this way the calcium oxalate* can be filtered immediately with suction and the precipitate perfectly retained on the filter. Filter, wash two or three times and remove filtrate for estimation of magnesia. Add to it 15 c.c. ammonium hydrate (0.90 sp. gr.), stand in a jar of cold water, agitate with a current of air, add 10 c.c. saturated solution of sodium and ammonium phosphate. Finish determination as usual.

While the magnesium phosphate is precipitating, the calcium oxalate is completely washed and set aside to be determined volumetrically with standard solution of potassium permanganate, 1 c.c. of which represents one per cent. CaO when one-half gram cinder is used.

Finally the precipitates of silica, alumina, and magnesium and ammonium phosphate, are ignited and weighed, and the calcium oxalate titrated. The four determinations are completed in about one hour. The various operations are greatly facilitated by having measuring tubes, flasks, beakers, reagents, etc., especially for the work, and located in the most convenient places. The solutions may be quickly boiled over a naked flame without cracking beakers if the flame is tipped

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* The filter paper containing the calcium oxalate is removed from the funnel and spread upon the side of the beaker in which the precipitation was made. The precipitate is washed down with a jet of water, and stirred till well disseminated. The paper is then spread upon the side of a large funnel, the beaker with precipitate placed under it, and boiling-hot dilute sulphuric acid (120 c.c. H_2O + 15 c.c. H_2SO_4 sp. gr. 1.84) is poured over the paper to dissolve off remaining traces of the precipitate. Stir contents of beaker. The calcium oxalate instantly dissolves. Titrate immediately, as the hotter the solution during titration, the more brisk the reaction.

with yellow. Two and three operations are carried on at once.

ZINC SULPHATE SOLUTION, AN ABSORBENT FOR H_2S.

In the evolution method of determining sulphur in iron and steel, I have lately been using an ammoniacal solution of zinc sulphate as the absorbent. It has proved quite satisfactory. It retains H_2S as readily and completely as do cadmium solutions. The precipitated sulphide is instantly dissolved when the absorbing solution is acidified. The amount of acid required is small and only a slight excess is needed. The reagent is inexpensive.

A stock solution is prepared by dissolving about 330 grams of dry zinc sulphate in 1,000 c.c. of water. After standing some time it is filtered if impurities appear. To 25 c.c. of this stock solution add 85 c.c. ammonium hydrate (0.90 sp. gr.) and agitate till the zinc hydrate redissolves. Add 2,350 c.c. of water. About 65 c.c. of this solution are used for each determination.

Riverside Iron Works,
April 16, 1897.

THE INFLUENCE OF THE GRAVITY OF GLYCERINE ON THE YIELD OF NITRO GLYCERINE.

BY W. E. GARRIGUES.

The commercial world's progress against the use of Beaumé's hydrometer scale is slow but steady, and one of the many arts that is gradually schooling itself to the point of entire freedom from its wiles is that of the glycerine refiner.

However much this advance movement is to be lauded, it nevertheless has its drawbacks, and as disturbers of commercial peace they are no mean ones.

When dynamite makers begin to ask for quotations on glycerine, whose gravity they specify to the fifth decimal place, it is apt to rattle one's enthusiasm for the rational scale a trifle at least, and may perhaps even cause a half longing

thought to stray back to the days of the less fine distinctions of Beaumé's hydrometer.

It has become common among high explosive manufacturers in this country of late, to claim of the glycerine producers an article above 1.262 specific gravity, and a recent case came under the writer's notice where a lot was actually rejected because it tested only 1.2615.

When we consider what these differences really mean in per cent. of glycerine lost to the buyer, the fancifulness of such strict requirements becomes apparent. If on the other hand the claim is put forth that it is not so much the loss of glycerine as the introduction of unnecessary and harmful water into the nitrating mixture that is objectionable, the case of the explosive maker is equally weak because of the utter insignificance of these infinitesimal quantities of water as compared to even a slight variation in the acids, the latter being used in the proportion of about 7 to 1 of glycerine.

Just how much water a sample of glycerine contains can hardly be ascertained, the various experimenters crediting 100% glycerine with different gravities. The five tables usually quoted as being the most satisfactory are those of Lenz, Strohmer, Gerlach, Nicol, and Skalweit, who record the specific gravity of anhydrous glycerine at 15 deg. C. respectively, as 1.2673, 1.2634, 1.2653, 1.266, 1.2650. Some of these were not determined at 15 deg., in which cases the writer has applied Hehner's correction of .00058 for each degree C.

Choosing from this array the figures of Gerlach and Skalweit, partly because they corroborate one another throughout and also because Morawski had cast the weight of his commendation into the scale for them, we find our dynamite glycerine to contain one per cent. of water if its gravity lies between 1.2625 and 1.2628, a density very seldom met with on the market.

The usual product of American refineries varies in gravity from 1.2608 to 1.2620, with 1.2615 as the common number,

while any offering below 1.2605 will be an exceedingly rare occurrence. By reference to the two tables we find that to contain 2% water, the gravity must be as low as 1.2600 to 1.2602, so that taking the two extremes 1.2600 and 1.2625 as representing without a doubt the range of variation in density of American dynamite glycerine, there is an extreme difference of only one per cent. in actual strength. It would be interesting to hear how many other liquid chemical industries attain such uniformity.

The question the writer has striven to answer in the above connection is: Does a variation of 2 to 3 points in the third decimal place of specific gravity, equivalent to a variation of 1% in glycerine strength, practically influence the yield of nitro glycerine as calculated on the actual quantity of glycerine nitrated?

To determine this, a commercial double distilled glycerine of 1.2572 gravity was secured, and after withdrawing a sample of the original for nitration the rest was concentrated by boiling under diminished pressure, at a constant temperature of 175 C. At intervals further samples were withdrawn, so that in all four were secured of the following densities: 1.2572, 1.2600, 1.2613, 1.2623. These were all nitrated under the same conditions and the following yields obtained:

Density.	Approximate per cent. Glycerine.	Per cent. Yield, as Obtained.	Per cent. Yield from actual Glycerine.
1.2623	99.0	230.8	
		231.7	
		231.9	
		233.0	
		233.0	
		235.3	
	Average,	233.0	235.3
1.2613	98.5	230.0	
		231.4	
		232.1	
	Average,	231.1	234.6

1.2600	98.0	230.1	
		231.0	
		233.0	
Average,		231.4	236.1
1.2572	97.0	226.5	
		227.3	
		231.0	
Average,		228.2	236.1

The results show conclusively that the small quantities of water present in commercial dynamite glycerines is without effect, and that at least above 97% or 1.257 gravity the comparative value of the glycerine is exactly according to its percentage strength—provided the mixed acids are of good quality. Those used in the foregoing experiments had the following composition: Sulphuric acid, 67.0%, Nitric acid, 26.1%, Hyponitric acid, 1.9%, Water, 5.0%.

The process of nitration was conducted as follows: A dropping bottle is filled to such a point with the sample of glycerine, that it will have delivered about 25 grammes when drained. This is weighed before and after the nitration, the difference being the glycerine used.

100 cc. of mixed acids, about 178 grammes, are placed in a dry beaker 2½ in. wide by 4½ in. deep, which is suspended in a large porcelain dish by passing through a piece of stiff cardboard. The cardboard is cut out to fit tightly around the beaker and is sufficiently large to completely cover the dish. This arrangement serves the double purpose of holding the nitrating vessel firm, and effectually preventing the splashing of any water into the acids, which would obviously be dangerous.

Cold water is allowed to circulate around the beaker throughout the operation, ice being used if necessary. When the acids have cooled to 10 deg. C. the addition of glycerine is begun, drop by drop, but at such a rate that the temperature rises to 20 in about three minutes, the mixture being meanwhile

stirred constantly with a short thermometer. The further addition is so regulated that the temperature remains between 19 and 21. When all is in and the mercury has fallen to 15, the beaker is removed from its improvised water jacket, wiped dry, and its contents transferred to a dry separating funnel, the beaker being rinsed with strong (1.84) sulphuric acid. The separation will begin at once if both glycerine and acids are what they should be, but it is best to allow the mixture to stand several hours, when it will be perfectly clear below the layer of nitro glycerine.

The acid is now tapped off and the upper layer run into 200 cc. of water at about 15 deg. Stir up well, decant, and repeat. Finally wash through a funnel into a narrow measuring tube graduated in 1-10 cc., let settle until volume remains constant at 15 deg., and take the reading, which multiplied by the specific gravity, 1.6, gives the weight of nitro glycerine.

This is the neatest manner of performing the nitrating test in the laboratory, though much time may be saved by running the whole mixture of acids and nitro glycerine, immediately after nitrating, into two litres of cold water, stirring meanwhile, then washing and measuring as above. This does away with the long wait for the clear separation, it taking place at once on contact with the water.

A comparison of the two methods has a bearing on the relative merits of the so-called direct and indirect separation, or separation and drowning as it is frequently termed. In Germany the wasteful process of drowning seems to be obsolete, but in this country many explosive works continue to enrich the rivers with countless tons of nitric and sulphuric acids yearly, much to the comfort of the acid makers.

It is interesting to note that the drowning process invariably returns a slightly better yield than the separation, but from the fact that in the former case the nitro glycerine is milky and opaque, as against opalescent to transparent in good separation

it is not unlikely that the apparent increased yield is due to contained water. The following comparative tests on the same sample of glycerine, nitrated with acids from the same drum, illustrate this difference:

Specific Gravity.	Per cent. Yield by Separation.	Per cent. Yield by Drowning.
1.2619	233.0	235.5
		237.0

It may be said, and justly, that the difference here is no greater than the variation of duplicates nitrated in the same manner. The figures, however, are chosen from a large number of trials with many samples of glycerine, and represent fairly the average observed difference. When several nitrations are made in each way, the average yield from drowning has in the writer's experience invariably been in excess of that obtained as the average of separating. It was also in every case easy to distinguish the product by appearance, as noted before.

Owing to its great viscosity, the accurate determination of the specific gravity of concentrated glycerine presents some little difficulty. The procedure employed in the writer's laboratory has been found quite satisfactory, and is as follows:

The sample, 50 cc., is gently warmed in a wide test tube fitted with a perforated stopper through which a thermometer passes. The bulb of the latter is pushed down in the glycerine and the tube is closed to prevent access of air. When no more air bubbles are visible in the sample, it is permitted to cool spontaneously, finishing by immersing to the full depth of the liquid in water, kept at just 15. In the meantime cool an ordinary 50 gramme picnometer to as nearly the same temperature as is feasible. When the thermometer registers 15 deg. in all parts of the test tube, remove the stopper and pour the glycerine into the picnometer in a thin, steady stream not more than half the size of the neck opening. This can be easily done without getting any bubbles. If it is attempted with a bottle instead of tube, it will probably fail, since any obstruction over which the thick fluid passes, such as it meets in the

shoulder of a bottle, is apt to cause the formation of air bubbles. Without immersion in the constant temperature water, the results are not satisfactory.

The Duquesne Chemical Laboratory,
Pittsburg, Pa.

A COMPARISON OF THE METHODS FOR THE DETERMINATION OF GLYCEROL.

With Notes on Standardizing Sodium Thiosulphate.

BY W. E. GARRIGUES.

Since of late years crude glycerine from soap factories, and even the untreated spent soap lyes themselves have become commercial articles—being sold by numerous smaller soap factories throughout the country to centrally located refineries—their accurate analysis, in view of the value of glycerine, has become a matter of no small importance. More especially is this the case with soap lyes since there is absolutely no other means of even approximating their worth.

This demand upon the resources of the analyst has been fully met by three modern processes, all of which are at present in use, and as each has its particular merit in certain restricted fields it is well to be familiar with all.

Arranging them in chronological order we have Benedikt and Zsigmondy's permanganate oxidation, Benedikt and Cantor's acetylation, and Hehner's bichromate, all of which appear in detail in the late works on oils and fats.

As already indicated, these methods are variously applicable, and it may be added, variously effective. While the last two are at the same time practically and theoretically correct, the permanganate process is to a certain extent empirical in that it returns only a fairly uniform percentage of the glycerine, about 95%, instead of the whole amount present. While this is not a generally admitted fact it is one nevertheless, a statement which the writer makes as the result of an extended experience with all three methods.

The following brief description of the processes in question, differs from the original in detail only, it being the manner in which the several methods are operated in the writer's laboratory. They are described as applied to spent soap lyes:

OXIDATION BY ALKALINE PERMANGANATE.

The sample containing about 2 grammes of glycerine, is decomposed with sulphuric acid, some pulped filter paper added to facilitate filtration, diluted to a known volume, and after passing through a dry filter to remove fatty and resinous matters, one-tenth is taken for the analysis.

Mix with 10 cc. saturated caustic soda and run in saturated permanganate until the liquid is no longer green, but blue or violet. Heat to the boiling point—longer than this is not necessary and hard on glassware—and after a few minutes' cooling in air, decompose the excess of permanganate with a saturated solution of sodium thiosulphate. Cool, dilute to 250 cc., filter out the manganese dioxide, and aliquot 200 cc. The glycerine has been converted to oxalic acid which is now in solution.

Acidulate slightly with acetic acid, boil and add calcium chloride. Filter out the calcium oxalate and dissolve through the filter in 10 cc. strong hydrochloric acid and 20 cc. of hot water, repassing several times if necessary. Wash until the liquid measures 200 cc., add 10 cc. strong sulphuric acid, warm to 60-70 and titrate with decinormal permanganate. 1 cc. equals theoretically .0046 gammes glycerol, but as stated above, the yield working on approximately these quantities should be increased 5%. More complete data regarding the titration of oxalic acid in hydrochloric acid solutions, may be found in the author's paper, this Journal, Vol. 12, p 139.

THE ACETIN PROCESS.

The glycerine solution must be concentrated to at least 60-70%, and since the method is not essential for the accurate valuation of lyes and suffers by comparison—for convenience—with the two others, and since it is at the same time the most

nearly accurate of all, and as such especially desired for the analysis of crude glycerines of high concentration, it will be described as applied to such samples as need no previous treatment.

1.5 grammes of the sample are mixed in a small flask with 8 cc. of acetic anhydride, and 3 grammes anhydrous sodium acetate. (The commercial anhydrous salt had better be powdered and dried in a water oven.) A reflux condenser is attached and the mixture boiled for $1\frac{1}{2}$ hours.

Pour in through the condenser 50 cc. warm water, and dissolve the tri-acetin by vigorous shaking. Dilute to 150 cc., cool, and after filtering remove 50 cc. to a capacious flask for titration, which dilute to 250 cc. Neutralize the free acetic acid with an 8-10% solution of carbonic acid free caustic soda, finishing for the sake of accuracy with a more dilute solution.

The amount of acetic anhydride that has combined with the glycerine can now be determined by simple saponification: Add 50 cc. semi-normal caustic soda to the contents of the flask and boil 15 minutes. Back titrate with semi-normal acid. Each cc. semi-normal alkali used is equivalent to .01533 grammes glycerine.

OXIDATION BY ACID BICHROMATE.

The solution of the lye, containing preferably one gramme of glycerine, is decomposed with sulphuric acid, 1-10 taken without previous filtration, and the chlorine precipitated with silver sulphate—added in powder until the supernatant liquid reacts with hydrochloric acid. Filter and add 15 cc. strong sulphuric acid, then 25 cc. normal bichromate and boil for three hours. (One-half to one hour's boiling as often practiced is certainly ineffectual.) The glycerine is completely oxidized to carbonic acid, the reduced bichromate being a measure of the quantity present.

Dilute to 250 cc. and draw off 25 cc. into a glass-stoppered flask, which mix with 10 cc. 10% potassium iodide solution and 5 cc. strong hydrochloric acid. After 15 minutes, dilute

with 150 cc. water and titrate the liberated iodine with decinormal thiosulphate. As 1-10 was taken and 1-10 normal solution used in the final titration, the volume of thiosulphate is simply subtracted from the volume of bichromate to get the cc. of the latter reduced by the glycerine. This multiplied by 0.006563, equals grammes of glycerine.

Obviously the excess of bichromate is capable of being determined in various ways, Hehner himself using a strong ferrous sulphate solution, and spotting out for the end point without aliquotting as above. Others again will prefer to aliquot, reduce with ferrous sulphate and back with permanganate.

The writer's preference is for the thiosulphate titration, and as no very precise literature seems to be available regarding this somewhat delicate process, a few remarks on this point will not be out of place.

The experiments were originally undertaken to ascertain the feasibility of standardizing thiosulphate from bichromate and permanganate, instead of going through the somewhat troublesome process of preparing dry resublimed iodine.

It was found, among other things, that the more acid was used to decompose the bichromate or permanganate, in contact with an iodide, and the longer the solutions were permitted to stand, the more iodine was liberated. While the cause was not investigated, it is no doubt due to the formation of hyrdriodic acid which slowly decomposes. Our purpose was simply to find what manner of treatment gave the theoretical iodine liberation.

It is unnecessary to give all the figures obtained, as they constitute simply a scale, increasing in cc. of thiosulphate used as the volume of added acid and time of standing were increased. Thus:

No. 1. 25 cc. N\10 $K_2Cr_2O_7$, 10 cc. 10% KI, 5 cc. HCl, no standing: took 25.23 cc. $Na_2S_2O_3$.

No. 2. 25 cc. N\10 $KMnO_4$, 10 cc. 10% KI, 5 cc. HCl, no standing: took 25.21 cc. $Na_2S_2O_3$.

No. 3. 25 cc. N\10 $KMnO_4$, 10 cc. 10% KI, 5 cc. HCl, 10 minutes standing: took 25.73 cc. $Na_2S_2O_3$.

No. 4. 25 cc. N\10 $K_2Cr_2O_7$, 10 cc. 10% KI, 5 cc. HCl, 10 minutes standing: took 25.75 cc. $Na_2S_2O_3$.

No. 5. 25 cc. N\10 $K_2Cr_2O_7$, 10 cc. 10% KI, 25 cc. HCl, 15 minutes standing: took 25.85 cc. $Na_2S_2O_3$.

No. 6. 25 cc. N\10 $KMnO_4$, 10 cc. 10% KI, 25 cc. HCl, 15 minutes standing: took 25.89 cc. $Na_2S_2O_3$.

No. 7. 25 cc. N\10 $K_2Cr_2O_7$, 10 cc. 10% KI, 50 cc. HCl, 30 minutes standing: took 26.20 cc. $Na_2S_2O_3$.

A deci-normal solution of iodine was then made by re-subliming from a lower to an upper weighed watch glass, according to Fresenius Quant. Analysis page 446.

25 cc. of this required of the thiosulphate, 25.70, 25.74, 25.75. As this is practically identical with results yielded by experiments Nos. 3 and 4, the proper conditions for either standardizing thiosulphate or determining chromic acid are: 25 cc. of solution containing the chromic acid, which mix with 10 cc. potassium iodide solution, of strength sufficient for the purpose, and 5 cc. strong hydrochloric acid. Let stand 10 minutes, then dilute with 150 cc. water and titrate the liberated iodine, stoppering and shaking violently between the addition of the few last drops of thiosulphate to redissolve the iodine in any precipitated iodide of starch. This precaution is an absolute essential to accurate work.

For purposes of standardizing, bichromate is recommended in preference to permanganate, even though the end point in the former case is a change from blue to green instead of colorless. In the case of permanganate the colorless end is almost invariably preceded by a brown to red change, which fades away only slowly and practically necessitates the use of an iodine solution to come back with. In this case the change is very sharp from colorless to clear blue.

Following are a few figures chosen at random from many trials, as showing the relative findings of the three methods for glycerine :

	$KMnO_4$.	$K_2Cr_2O_7$.		Acetin.
A candle crude,	87.5	87.9		88.1
A soap lye crude,	90.6	90.2		90.4
A dynamite glycerine, Sp. gr. 1.2626.	99.6	99.3		99.7
		1-hr's boiling.	3-hrs' boiling.	
A spent soap lye,	5.69	5.60	5.71	5.79
	5.74	5.63	5.77	
	5.80		5.79	

In all the first column results, a practically pure glycerine was taken as a standard, which caused theoretical results to be corrected by the factor × 1.049.

There must be something very mysterious, to say the least, in the composition of English spent soap lyes, since both Alder Wright and Lewkowitch, in their late works on oils and fats, go through such intricate schemes to determine the glycerine content of lyes. In fact any one reading either work on the subject, would certainly conclude it to be the author's opinion that the analysis of lyes was a very unsatisfactory undertaking at best and ought to be let religiously alone. Lewkowitch's scheme especially is burdened with such thorough manipulative clumsiness that there is very little danger of any analyist ever trying it.

When three such widely varying processes as these described in this paper, give practically identical results, and more important still when the pure finished glycerol comes out of the finishing pans in quantity to corroborate these analyses, there is surely no room for doubt as to the accuracy of the analytical finding. This manner of checking an analysis has been much derided, but under these circumstances there could be nothing more satisfactory. The perfection of the refining and recovery plant can always be demonstrated by putting finished glycerine through the whole process.

Many comparative trials show that it is of no benefit in assaying lyes or crudes made from lye, to employ lead acetate as a purifier previous to applying any of the methods. Sulphuric acid is all that is required. Silver sulphate or oxyde must always be used to get rid of chlorine for the bichromate process, and in the case of candle crudes lead acetate can be added also, as there appears to be a little organic matter present capable of forming insoluble lead compounds and that reduces chromic acid. All crudes are, however, best worked by the acetin process and lyes by bichromate. Permanganate is especially useful in the case of recovered salt, which contains so little glycerine that it requires a very large amount of silver to separate the chlorine from enough of it to work on with satisfaction.

The Duquesne Chemical Laboratory,
Pittsburg, Pa.

MEMORIAL ON THE DEATH OF MR. DAVID A. STEVENSON, DECEASED.

PITTSBURG, PA., April 23, 1897.

The subject of this sketch, Mr. David A. Stevenson, was born in Genesee Co., New York, May 24, 1845, his parents soon after removing to Illinois. He received his education at Monmouth College. At the age of twenty-three years he began his life as a railroad man, having obtained a position on the corps of the resident engineer of the Western Division of the Pennsylvania Railroad.

When the Maintenance of Way Department of this road was organized, Mr. Stevenson was appointed Chief Clerk of M. W. for the Pittsburg Division. This responsible position he faithfully filled for the lengthened term of twenty-nine years, covering as it does the wonderful development of practical railroading in this country. To this movement he contributed his share, both by faithful work and thorough system, as the many forms now in use, of his design, will testify.

He was a man of singular social qualities, of great industry, and few have filled such important positions so satisfactorily to their superiors, and at the same time retained the respect and attachment of their fellow workers.

He was elected a member of the Advisory Board of the Pennsylvania Railroad Voluntary Relief Association. The value of this tribute to his work is seen when it is remembered that the membership of this Association is over 40,000, and that, of the twelve members of the Board, but six are elected by the membership.

Other societies have shown a like appreciation of his devoted services, he being elevated to the 33d degree in Masonry, and having filled some of the highest offices in that order. He served also a number of years as School Director in his ward.

Mr. Stevenson ever retained his interest in engineering and kept up his membership when engrossed in other duties. Joining the society in May, 1883, his third term of active membership came at a time when the society most needed such aid as his popularity and talent for organization could give.

Cut off in the midst of his activity and usefulness, he fell a victim of pneumonia and after a short and severe illness found relief in death on the evening of January 8, 1897.

Few of our citizens have been followed to their last resting place by so many friends, or so sincerely regretted as our departed fellow member.

Daniel Carhart,
L. C. Weldin,
Committee.

Engineers' Society of Western Pennsylvania.

The regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Lecture Room of the Society's House, 410 Penn Ave., Pittsburg, Pa., Tuesday evening, May 18th, 1897. Vice-President, George S. Davison, in the chair.

The meeting was called to order at 8 o'clock, about one hundred and twenty members and visitors being present.

The minutes of the last meeting were read and approved.

Messrs. E. L. McGary and James R. Moore were duly elected members of the society by nineteen votes. Messrs. Wendt and Cunningham being the tellers.

The Chairman announced that the next order of business was unfinished business, and that a discussion of the New Constitution was in order.

Upon a motion of Mr. Ridinger, the consideration of unfinished and new business was postponed until after the reading and discussion of the regular paper for the evening.

Mr. Davison stated on behalf of the committee which had been appointed to bring the matter of proper qualification in the person of the director of public works, provided for in the proposed new charter for Pittsburg, that the committee had been appointed too late to confer with the legislative committee having the new charters in charge. He stated, however, that the committee had been able to do a little in the way of bringing the matter to the attention of the legislature, prior to the general discussion of the new charters, and that the committee would act as they thought best when the question came up for final disposition.

Mr. Morse, as chairman of the committee on the Dalzell Bridge Bill, reported that the committee had done nothing, for the reason that the bill, although it had been introduced at this Congress, would not be discussed at the present session. He stated that the committee would keep the matter in hand and take proper action when the bill was again introduced.

The death of Mr. Fred Herron was announced by one of the members, and, upon vote of the Society, the chairman was instructed to appoint a committee to prepare suitable memorial resolutions. The committee was not appointed at this time. The reading of Mr. Fisher's paper was then proceeded with.

ELECTRIC CURRENTS OF HIGH FREQUENCY AND X RAYS.

BY H. W. FISHER.

ILLUSTRATED EXPERIMENTALLY.

Foremost, perhaps, amongst the pleasures of engineering and scientific investigations are those afforded by the opportunities of original work and research. In engineering, the forces of nature are made subservient to man, for his benefit and comfort.

Any person may admire the grand results obtained, but it takes the skilled engineer to fully appreciate the work of the designer, or to be startled at his pleasing or bold originality.

Perhaps the greatest inward pleasures attend those grand persons who, solely from their deep love of nature, spend their time in trying to unravel some of her many mysteries; and how nobly have they succeeded in paving many of the avenues of human progress and happiness.

When, therefore, I was asked to read a paper before this Society, upon subjects which belong largely to pure science, I was filled with feelings of my incapability of presenting them in even a creditable manner, and so I will ask your kind indul-

gence if I omit scientific reasonings with reference to the subjects in hand, and confine myself to a description of what progress has been made in them ; a few theories concerning them, and subsequently, by experiment, to the exhibition of many interesting and beautiful phenomena.

There has been such an enormous amount of scientific work done in the past few years that now, when an apparent discovery is announced, there are comparatively few persons who are thoroughly capable of judging, off-hand, whether the discoverer has announced something really original.

For instance, the admirable work of Mr. Nicola Tesla led many persons to believe him to be the originator of electric currents of high frequency, and yet it was well known for many years before, that under the right conditions the discharge from a condenser may rapidly oscillate, and that when these oscillatory discharges are carried through a wire, similar discharges will be generated in adjacent wires.

Never having attempted any original work with electric currents of high frequency, I can do no better to-night, than to speak of the work of Mr. Tesla, and reproduce some of his experiments on a small scale.

Tesla strove to obtain a more efficient form of light than we can now get by artificial means. His idea was that if electric waves could be made as short as light waves we would have an intense source of illumination.

This idea was based, in part, upon his experiments, which showed that when the frequency is very high the air breaks down readily, and the discharge from electrified wires changes from the characteristic blue to a bright white color. Hence, he reasoned, could the frequency be high enough, the blue discharge would be entirely supplanted by a brilliant white light.

At present it seems impossible by any known means, to obtain electric waves as short as those of light.

I believe the shortest electro-magnetic waves so far obtained are in the neighborhood of 100,000 times the length of light waves.

Mr. Tesla constructed an ingenious alternator, from which he obtained currents of a frequency of 10,000 per second.

By using a condenser and high frequency coil, in conjunction with this alternator, he was able to increase the frequency to over a million per second.

He has invented and used many other devices for increasing the frequency, which I have not time to mention here.

No iron core can be used in the construction of a high frequency disruptive discharge coil. The primary and secondary windings are heavily insulated, and are submerged in oil. I have here a small coil from which I have obtained over 150,000 volts. By means of suitable transformers, I can obtain six thousand volts. The current from these transformers passes through an interrupter to the primary of my coil.

The interrupter consists of a rapidly-revolving aluminum wheel, with 20 long arms, and two stationary rods, which can be adjusted so as almost to touch the ends of the arms. Every time one of the arms comes opposite the stationary rods there is a disruptive discharge from the condenser through the coil. The condenser is connected in multiple arc with the wires from the transformers.

The frequency of this coil is so great that a person does not experience any unpleasant sensation in receiving a shock from it. The reason for this is believed by many to be the tendency for the discharge to keep on the outside of one's body. Others believe that the action of the nerves is too slow to be affected by the discharge.

I take a conducting body in my hand and approach it to the coil, and immediately bright sparks jump several inches through the intervening air space.

If I place a blank book between my hand and the coil, a spark pierces the book, and almost instantly, sets fire to it. This shows that there is a good deal of energy in this discharge.

The voltage which I have just received lies between 60,000 and 100,000 volts.

You will notice the beautiful brush discharges at the terminals of the coil. I have here a large circular ring of wire and a metallic ball, placed in the center of it. I connect one terminal of the coil to the ring and one to the ball, and immediately the intervening space becomes beautifully illuminated with brush discharges.

I have here a number of vacuum tubes of varying construction, and of different degrees of exhaustion. These become beautifully illuminated when connected with a wire running from one terminal of the coil. This illustrates the one-wire system of illumination proposed by Mr. Tesla. I was unfortunate in not being able to get one of his lamps, which are specially designed for high frequency coils. These have one leading in wire, and at the end of it a refractory button which becomes very brilliant when the lamp is attached to the coil.

I believe it will be impossible to use this system in practice, on account of the great difficulty of insulating the wires and fixtures.

You can readily see, from the luminous appearance of the wires and the big sparks one receives upon approaching the hand near them, how unpracticable the system would be in the light of our present knowledge.

Up to the present I have shown you how vacuum tubes can be lighted, when connected to one terminal of the high frequency coil. I now propose to show you a most interesting experiment, where tubes of this kind can be brightly illuminated when they are not at all connected with the high frequency coil.

I have here a couple of large plates which are placed on insulators. I will connect one of these to one terminal of the high frequency coil, and the other plate to the other terminal.

I will now start the coil to work, and you notice that the minute that I place any of my vacuum tubes between these plates, that they become beautifully, and even brilliantly,

illuminated. This is caused by the electro-static action between the plates, and in it is illustrated the method of lighting lamps to which there are no actual wire connections.

It is believed that the Aurora Borealis is caused by a similar action to the above ; and there is no doubt that if the space between these plates could be a partial vacuum, that the effect would be beautiful, and not unlike the Aurora Borealis.

Mr. Tesla's lecture before the Royal Society, England, showed what thorough work he had done with currents of high frequency, and the way he analyzed many of the singular phenomena observed by him was striking and interesting. He also exhibited a number of original forms of lamps.

My time is too limited, to-night, to discuss any of these, but his lecture, in full, is contained in the Electrical World, Vol. 19, No. 19, and also in his book on High Frequency Currents.

He predicted that lamps of the type proposed by him would be twenty times more efficient than incadescent lights. Many of the refractory buttons used in his lamps were made of carborundum, manufactured at Monongahela City. This substance seemed to withstand the intense heat of the gas surrounding it, better than anything he had tried.

And now I wish to say one word more about the difficulties of obtaining very high frequencies. The alternating current which I am using to-night has a normal frequency of 133 per second, and, consequently, the electro-magnetic waves from it are over 1,300 miles long. Compare this with the light waves 1-60,000 of an inch long. I believe by the use of rapidly rotating or oscillating mechanical devices, electric waves of from three to six miles long have been obtained, and the possible limit can not be far from this. These waves may further be broken up by means of multiple points and an air blast; or, by a strong magnet placed across the spark gap. Furthermore, these impulses may be broken up by means of a

condenser of an electro-static capacity which bears the correct relation to the self-induction and resistance of the coil to make the discharge oscillatory.

But it is only with extremely small condensers that the conditions for very high frequencies and short waves are obtained. I believe condensers about the size of a thimble were used to obtain waves about an inch long.

Hence, in the light of our present knowledge, we can not ever hope to be able to make electro-magnetic waves as short as light waves.

I have here a large, high frequency coil, which gives two or three hundred thousand volts. The primary circuit consists of two coils of 17 turns each, which can be used either in multiple or series. The secondary has 506 turns of No. 20 B. & S. Gauge cotton covered wire. No. 12 B. & S. Gauge cotton covered wire is used in the primary. The layers are separated with strips of paper, and all the material was boiled in paraffine oil before and after the coil was wound. The coil is completely submerged in oil, which prevents internal discharges that would soon render it inoperative.

To illustrate how a lamp can be illuminated when only connected to one wire, I have stretched a wire across this hall, and connected a lamp to the far end of it. I connect this wire to one side of the coil, and you will notice that the whole wire emits a bluish discharge, while the lamp gives a soft white light. The effect would be much more brilliant had I the right kind of lamp.

To illustrate some of the novel and beautiful discharges which can be obtained with high frequency currents, I have here a large plate of glass an inch thick. On the back of this plate, I place a sheet of metal, which is connected to one terminal of the coil. The other terminal I will connect to a small circular disc on the opposite side of the glass. Immediately upon putting on the current the plate is covered with innumerable discharges of varying forms. I change the electro-

static capacity, and put a different shaped piece of sheet iron at the back of the plate, and I can either make brilliant white discharges covering the entire plate, or else a few large discharges from which proceed a number of smaller ones, leaving a picture upon the eye not unlike a fern.

It is no easy matter to determine accurately the frequency of a high frequency coil. The following method is one which has occurred to me, and I would very much like to hear a discussion of it at the close of the meeting. A special photometer is arranged with two sets of binding posts, accurately placed at equal distances from each side of the oiled screen. Between each set of binding posts is fastened a wire, the direction of which is parallel with the plane of the oiled screen. The distance between the sets of binding posts is the same and is accurately known. The wires should preferably be of platinum, accurately drawn so that each has the same diameter. The high frequency current going to the primary circuit passes through one of these wires, a size of wire having been selected which is brought to a bright redness by the current. A dynameter is placed so as to measure the current flowing through this wire before said current has been made to oscillate. The other wire is brought up to the same luminous intensity by means of current from a direct current dynamo and a suitable rheostat, the point of equal luminosity of the two wires being determined by the photometer in the usual way. At this juncture the current flowing through both wires is measured, as well as the voltage across the wire, which carries the direct current. From the current, voltage, and size and length of the wire, the resistivity of the wires at the time of the measurements can be calculated. We can assume that the same amount of energy has been developed in each wire, and hence by using the well-known formula representing electrical energy, viz: C^2R—we have an equation all the terms of which are known except the resistance offered to the high frequency current which we can consequently determine. Having this then, to-

gether with the size and resistivity of wire, the frequency can be calculated by Lord Kelvin's formula, which gives the increase in resistance due to the so-called "skin effect," a discussion of which is found in Part II., Vol. II., of Gray's "Absolute Measurements in Electricity and Magnetism."

I can easily illustrate the fact that when the frequency is high, the current tends to follow the outside of the wire. I have here two wires of the same size, both of which are traversed by the same amount of current. You will notice that the wire conveying the oscillating current is melted almost instantly, while the other is not preceptibly heated. Moreover, I have a lamp so arranged that the current coming to my body from the coil passes through the filament of the lamp. You will notice that the filament becomes red. The amount of ordinary current that would bring it to that degree of redness would "be instantly fatal."

I have here two pieces of rubber-covered wire, especially made for this lecture by the Standard Underground Cable Company, and capable of withstanding over 100,000 volts between conductors. I will connect these to the terminals of the coil, and bring the insulated covers close together. You will notice the blue discharges that play back and forward between the rubber covers of the wires. These do not actually pierce the rubber, but are only an electro-static manifestation. As I increase the voltage, the discharges become beautiful and even brilliant. I have now over 200,000 volts between the wires, and yet the rubber has not been destroyed.

It is really remarkable how much a well-made cable insulated with the best rubber will stand.

There are many other interesting features of high frequency currents, but I must leave them now to speak of the second subject, X Rays.

"X" RAYS.

After the able lectures on X Rays which have been delivered here by some of our noted scientists, I feel that I

have little to say on the subject. However, as all present may not have heard these lectures, I will make a few brief remarks and then pass on to an exhibition of some interesting X Ray experiments.

But for the work of Hertz and Lenard the discovery of X Rays would probably not yet have been made. There is no doubt that Lenard unconsciously experimented with X Rays, for some of the results obtained by him could not have been entirely due to cathode rays.

Roentgen made the following statements with reference to his discovery of X Rays in his original paper: They can not be reflected; they cause many substances to fluoresce; they can not be refracted nor polarized.

He did not consider X Rays to be of the same nature as ultra-violet nor infra-red rays. He suggested that they might be longitudinal waves. Not being able to determine what they were, he called them X Rays, from the accepted use of X in algebra, to represent an unknown quantity.

Roentgen's paper was a model of brevity and thoroughness. Perhaps the only valuable addition to the discoveries announced by him is the discovery of J. J. Thomson, that X Rays make insulators and gases become temporary conductors, and even this was discovered by Lenard, who attributed the action to cathode rays when, in reality, there is but little doubt that X Rays caused the phenomena in some cases.

The letter X is still applicable to Roentgen Rays, for we do not yet know what they are.

Mr. Tesla and others are inclined to the belief that they are rapidly-moving electrified particles. Others consider them akin to ultra-violet light rays, and even Prof. Roland made a calculation which gave the length of the wave to be one-seventh that of yellow light. Several other theories have been advanced, but all theories are open to objection.

The rays are best obtained by the use of a reflector that causes the cathode rays to impinge on the anode, which is

usually a piece of platinum foil placed at an angle of 45 degrees, so as to project the rays normal to the glass tube. For high-frequency currents there are two cathode reflectors to which the wires from the coil are attached, and between them a V-shaped anode upon each side of which the cathode rays from the reflectors impinge.

I believe the best results are obtained by the use of induction coils, and apparatus that gives uni-directional currents. Very good results, however, can be obtained by high frequency currents, when adjusted to suit the tubes. I have found that my tubes work the best with high frequency currents when the anode is hottest; whereas, this, I believe, is not generally true with induction coils. There is every reason to believe that there are different kinds of X Rays. Of two tubes that I used, one gave sharp definitive, and the other a certain blurred appearance; and yet, with the latter I could see much better through the body, being easily able to see the heart beating, and the movement of the diaphragm. In order that I may not be misunderstood, I wish to qualify this statement by saying that the difference in the sharpness of the shadow cast by these tubes is attributable to the mechanical construction of the tubes, and not to the kind of X Rays generated. The fluorescent screen seemed equally bright when looking at an object through which the rays passed readily; but, when looking through the body one tube gave much better results than the other.

It is now a well-known fact that, occasionally, X Rays have a temporary injurious effect on the skin of the body. The rays from all tubes do not seem to affect the skin to the same extent. There are many theories to account for this action, but, as yet, I believe, the phenomena is not understood.

Mr. Tesla has done some good work to try to counteract the injurious effects of X Rays on the skin. He recommends placing a thin screen of aluminum between the body and the tube, and he connects this screen to the ground by means of a

wire. He also claims that this effect takes place only when the subject is close to the tube, and that beyond 16 inches, when the screen recommended by him is used, there are no injurious effects, even with the most powerful tubes now known. Mr. Tesla thinks the soreness of the skin may be due to three things.

First, the thermal effect. Considering as he does X Rays to consist of rapidly moving particles, the temperature caused by the impact of these against the skin he claims might be as high as one hundred thousand degrees centigrade, and this, of course, would tend to burn the skin.

Second, an electrical effect. The moving particles would naturally be very heavily charged with electricity, and their combined charges would cause local currents in the skin which would have a tendency to destroy the tissues.

Third, an electro-chemical effect. The charged particles would generate large quantities of ozone and other gases which are known to have an injurious effect upon the tissues.

I had occasion to take two X Ray photographs—one of the hand, and the other of the body, of a friend of mine, and the sufferings he subsequently endured from the X Rays were so alarmingly severe that as a warning to those using X Rays I cannot perhaps do better than to describe them here.

Having taken a number of photographs previous to the ones alluded to, and there being no injurious after effects, I was greatly surprised and mortified when my friend dropped in upon me 19 days after I had taken the photographs, with his hand bandaged and very much inflamed. The time of exposure for the body photograph had been 53 minutes, and his hand was subjected to the rays for five or ten minutes. He informed me that 12 days after the photograph had been taken his chest became very sore, and gradually turned quite dark in color; after which, in the course of a day or two, the outer skin peeled off, leaving the inner skin very sore, as in the case of a burn. Fifteen days after the photograph had been taken

his hand commenced to be affected, and it swelled considerably and became very sore. My friend seemed to think that both his hand and chest would heal rapidly, and so I thought his case would be similar to others reported in the electrical papers. He is a very busy man, and as I was deeply engaged at spare moments in the preparation of this paper, I did not feel uneasy at not hearing from him. Last week I happened to hear that he had suffered extremely, and so I immediately went to see him. I learned from him that the outer skin at the back of his hand came off, and the new skin looked so healthy that the Doctor told him his hand would soon be all right. Several days later he noticed a very disagreeable odor which seemed to proceed from his hand. He went to the Doctor, who immediately laid back the skin, and then discovered that blood poisoning had set in. This was scraped off, and the flesh thoroughly cauterized, and his hand was practically well when I saw him. The Doctor, however, said that had the operation been deferred a day or two, his hand, in all probability, would have had to be amputated. This was over five weeks after his exposure to the X Rays. His chest at that time was very sore indeed, being raw for a space bigger than a man's hand; the new skin had gradually been growing around the edges of this sore place, but from appearances it looked as though several weeks would pass before the skin would grow all over.

The singular part of this is the fact that I took a photograph of the hand of a boy, aged 6½ years, at the same time, and at the same distance from the tube. The boy's hand was exposed for three minutes, and my friend's hand for five. The boy's hand did not become sore. One would think, that unless soreness is caused in all cases at a definite time of exposure, three minutes for a child of 6½ years would certainly be as hard as 5 minutes for a man. I am of the opinion that the bodily condition of the person may have something to do with it. My friend was considerably run down at the time of exposure to the Rays.

I propose, to-night, to show you X Rays as generated by high frequency currents, and by an induction coil. Through the kindness of Prof. Fessenden, I have here a powerful induction coil, and a large Fluorescent screen. I will place different objects back of the screen, and you will see the relative power of the X Rays in penetrating them. The Fluorescent part of this large screen consists of Barium Platino Cyanide and the small one of calcic Tungstate, which was discovered to have the property of fluoresence by Mr. Edison.

I presume that those at the other end of the lecture room will have difficulty in seeing the objects on this screen, and at the close of the lecture there will be an opportunity for individuals to use the hand fluorscopes to look at objects of interest.

The X Ray tube I am going to use to-night has given me excellent results. It was made by Queen & Co., of Philadelphia, and it has a self-regulating device, by means of which the vacuum can be kept fairly constant. I place my hand and arm between the screen and tube, and you can see the bones and flesh very distinctly. And now I will place the screen in front of a person. You can easily see the pulsations of the heart and the movement of the diaphram. How wonderful a manifestation this is.

DISCUSSION.

Mr. Hirsch. Is the difference in the color in the glass tubes caused by a difference in the degree of vacuum only?

Mr. Fisher. The difference in color is caused principally by difference in the degree of vacuum, but it is also caused to a certain extent by uranium in the glass.

The question was asked if it was possible to transmit the high frequency power to any distance.

Mr. Fisher. No, it is not practicable at present. There would be a very great loss in transmission. This kind of current is very hard to transmit as it is almost impossible to completely insulate it.

Mr. Davison. I think we will all agree that the exhibition this evening beats Fourth of July at Schenley. I think that the Society is greatly indebted to Mr. Fisher, not only for his very able paper, but also for the amount of trouble and expense which he has gone to in order to give the brilliant experiments connected with his lecture. I think it would be strictly in order for some member to make a motion in behalf of the Engineers' Society of Western Pennsylvania, thanking Mr. Fisher for his paper and the splendid exhibition he has given us.

I would also say that I am pleased to see so many visitors here this evening, and would, in behalf of Mr. Fisher, who is a very modest young gentleman, invite them to remain until the regular business of the Society is finished, when they will be given an opportunity to examine the X-Rays machine personally.

I would like to hear opinions from Mr. Lewis, and Mr. Brashear, and any other member present this evening, on this most interesting subject.

Mr. Hirsch. I move that the society extend to Mr. Fisher a vote of thanks for his very able paper and the wonderful experiments illustrating it.

The motion was properly seconded and carried.

Mr. Scott. This evening's lecture has been replete with experiments of a very wonderful character, and the apparatus shows the most painstaking preparation and adjustment. I do not think I have ever listened to a lecture of this character where the experiments were carried on with such perfect success, and Mr. Fisher is to be very highly complimented upon both his paper and the experiments.

Mr. Brashear. Mr. Chairman, I feel about five years younger this evening. I have never listened to a lecture which delighted me as much as this one has. I had a couple of tickets for a concert this evening, but I gave them to the servant and said I was going to a lecture. I do not think

those who attended the concert enjoyed it one-half as much as I have enjoyed this lecture. I have heard such lectures as these in Columbia College, and had the pleasure of hearing Prof. Dewar, in the Royal Institution, but I am sure that none of the experiments came up to the experiments which were given this evening by Mr. Fisher. And then again, Mr. Fisher was so perfectly cool in all that he did! When I saw him going through these experiments I was afraid that the next minute we would have no Fisher, but everything was a perfect success. There is one thing, however, I would like to say in connection with this matter, and that is to call attention to the "dead work that has been done," to prepare for such an exhibition as was given here this evening, but taking this into consideration we certainly should feel very grateful to Mr. Fisher for his lecture and beautiful experiments.

Mr. Davison. The chair decides that neither the remarks of Mr. Scott nor Mr. Brashear have done justice to the subject. They have tried hard to express the indebtedness of the Society to Mr. Fisher, but they are not equal to the occasion.

It was here suggested that the chairman express the sentiments of the Society, but he declined to do so.

Mr. Fisher. Mr. Chairman and Gentlemen, I wish to say that I feel very highly honored by the complimentary remarks of the chairman and other members of the Society. Of course I acknowledge that it took a great deal of time and hard work to prepare the apparatus for the experiments, but it has been a very great pleasure to me to give them; and in preparing for them I knew that if I presented anything worthy of the electrical science it would be appreciated by the members of the Engineers' Society. I thank you heartily for your kind attention.

Mr. Davison. Inasmuch as the evening is pretty well advanced, and there being no desire for further discussion, I would suggest that a motion to postpone the discussion on the constitution until the next meeting be made. This will give

the members and their friends an opportunity to examine the X-Ray machine and other electric apparatus.

Mr. Engstrom. I move that the consideration of the new constitution be postponed until the next regular meeting.

This motion was properly seconded and carried.

Mr. Davison. I would like to call the attention of the society to the fact that the Hon. John Dalzell has recently presented to the Society a large number of public documents, and it would be in order for the society to take cognizance of this, and instruct the Secretary to acknowledge receipt of them with proper expressions of appreciation.

Mr. H. O. Lewis. I move that the Secretary be instructed to write to Mr. Dalzell acknowledging receipt of these documents, and extending to him the thanks of the Society.

Motion seconded and carried.

Mr. Davison. A member of the Society asked me to bring up this evening the matter of a summer outing of the Society. I only mention this matter at the request of this member. Does the Society wish to instruct the reception committee to prepare for such an outing? For the last two or three years we have had an annual outing, and also at the time of the visits of some of our engineering friends. If it is the desire of the Society to have an excursion, or outing of some kind this summer, this evening is the proper time to bring it up, as the next monthly meeting in June will be the last until next fall, and if the Society wishes an outing, it must instruct the committee this evening in order that it may report at the next meeting.

Mr. Scott. I move that the reception committee be instructed to consider this matter and report at the next meeting.

Motion was seconded.

Mr. Davison.—Do you intend to give them power to act?

Mr. Scott.—I do not think it would be best to give them power to act, but only to report, and then the Society could decide what was best to do.

Mr. Lewis.—I do not think that would meet the emergency in this case. I think the reception committee should have the matter pretty well in hand; know where to go, what the cost would be, and have all the preliminary details settled before the next meeting of the Society.

Mr. Davison.—The only question is, whether the motion as made, would give the committee power to act and make positive arrangements.

Mr. Lewis.—I do not think that has been a precedent in the past.

Mr. Davison.—It was put in the hands of this committee on one or two occasions.

Motion was passed as originally made.

Upon proper motion meeting adjourned.

Reginald A. Fessenden,
Secretary.

MEETING OF THE CHEMICAL SECTION.

PITTSBURG, PA., May 20th, 1897.

The regular monthly meeting of the Chemical Section of the Engineers' Society of Western Pennsylvania was held in the Lecture Room of the Society's House, 410 Penn Ave., May 20th, 1897.

Vice-Chairman K. F. Stahl presided.

Attendance, 14.

The minutes of the last regular meeting were read and approved.

Dr. F. C. Phillips read a paper on "The Explosive Properties of Acetylene."

THE EXPLOSIVE PROPERTIES OF ACETYLENE.

BY FRANCIS C. PHILLIPS.

The success attained in the early experiments with acetylene as an illuminant led to a demand for the gas in compressed or liquefied form convenient for transportation and use.

It was found, however, that when inquiries were made of those who were interested in the development of the industry, the reply was always to the effect that while calcium carbide was regularly on sale, acetylene could not be bought. Delays incidental to the establishment of a new branch of manufacture may have had much to do with the fact that acetylene was not at once offered for sale, but it seems probable that the failure to supply the gas may have been due to some extent at least to a knowledge that it is liable, under certain conditions, to undergo explosive decomposition, and that serious dangers might attend its compression or liquefaction in iron cylinders after the method so long in use in the case of nitrous oxide, carbon dioxide and other gases. Much has been written recently upon explosions of acetylene, but statements were current as to its tendency to undergo sudden and dangerous decomposition long before any accounts of actual explosions were made public.

The occurrence of several violent explosions of liquefied acetylene has drawn attention anew to the possibility of accidents from its use, and its more general introduction for illuminating purposes is likely to be delayed until the real cause of such explosions is clearly understood, and their avoidance rendered possible. Berthelot was probably the first to observe the peculiar instability of acetylene. In his work, "Explosives and their Power," p. 69, this author describes an experiment in which acetylene is completely decomposed by the detonation of mercury fulminate. The acetylene is contained in a thick walled test tube closed by a brass cap. The fulminate is fired by an electric fuse. "The fulminate goes off, a violent explosion follows and a large flame appears in the test tube. After cooling the tube will be found filled with black, finely divided carbon, the acetylene has disappeared, and free hydrogen remains. The acetylene is thus purely and simply decomposed into its elements, carbon and hydrogen. Scarcely a trace of the original gas will be found, and, if any, it will not be more than a hundredth of a cubic centimeter."

Berthelot determined the heat evolved during the decomposition of acetylene, which he found to be 51.4 calories per gram molecule (26 grams). This would mean that by sudden decomposition of acetylene in a closed vessel a quantity of heat is produced sufficient to raise the temperature of the liberated hydrogen and carbon to 2,750° C.

The heat of formation of water in gaseous state (58.2 calories) is only about one-fifth greater in quantity than that produced when acetylene separates into its elements, carbon and hydrogen (51.4 calories), supposing that the molecular weight expressed in grams is concerned in both cases.

In this respect acetylene differs in a remarkable manner from the various compounds which form the chief constituents of illuminants and fuels. It is one of a class of compounds which are, under certain conditions, extremely unstable, and stand related to the high explosives.

Such facts suggest dangers in the use of the gas and the occurrence of several accidents resulting in the destruction of life and property has tended to show that the theoretical possibilities are liable to be fully realized in practice.

The information gained directly from such accidents is incomplete, although in a few instances enough has been learned to prove that explosion, as the term is ordinarily understood, namely, the ignition of a combustible gas mixed with air, was not the cause.

An explosion occurred in October, 1896, in the acetylene factory of Raoul Pictet, in Paris. An iron cylinder, while undergoing repairs, exploded with great violence. The walls of the building were partly demolished. Wood work was destroyed and windows at a considerable distance were shattered. Two workman were killed and a third injured. This explosion was rendered especially interesting by the fact that a considerable quantity of carbon in the form of lamp-black was deposited in the room. From the force of the shock it seemed impossible to attribute the explosion to the ignition of a residue of gas mixed with air in the vessel. The pieces of the shattered cylinder were finally collected together and it was identified as one of a lot which had been received at the factory to be refilled. This cylinder had apparently been returned by mistake nearly full of liquid acetylene. When fully charged, these cylinders contained three and one-half kilos of acetylene. A commission of scientific experts, among whom were members of the French Academy, was appointed to investigate the cause of the explosion. No positive conclusion was reached by this Commission, although it appeared probable that the explosion was due either to the employment of too great force in opening the valve, causing friction and heating to the point of decomposition of the acetylene, or to the formation of copper acetylide upon the copper parts used in the valve fittings. (Journal für Gasbeleuchtung and Wasserversorgung, 1896, p. 795.)

In December, 1896, an explosion occurred in a factory in Berlin, causing the death of four men. It is said that experiments were being made in this establishment having for their special purpose to explain the cause of such accidents and to indicate the means for their prevention. Nothing is known of the manner in which this explosion occurred. (Journal für Gasbeleuchtung and Wasserversorgung, 1896, p. 843.)

There can now be little doubt that acetylene is liable to undergo explosive decomposition, and that it may rupture the strongest iron cylinders in use for holding compressed gases.

Berthelot & Vieille (Compts Rendus, Oct. 5, 1896) have published some results of investigations upon the explosive properties of acetylene of which the following is a summary:—When under atmospheric pressure an explosive wave is not propagated through acetylene. Neither an electric spark, nor a heated wire, nor the detonation of mercury fulminate, can be made to cause decomposition beyond that portion of the gas which is directly exposed to such influence.

At a pressure of two atmospheres, and above, the case is different.

Decomposition caused at a single point by an incandescent platinum wire is rapidly spread through the entire volume of the gas, with scarcely diminished effect.

Pressure promotes the propagation of an explosive change in this as in other endothermic gases.

In a series of experiments, in which the pressures were measured, it was found that acetylene under a pressure of 2.23 kilos per square centimeter, when exploded by a heated platinum wire, developed a pressure of 8.77 kilos. At an original pressure of 21.1 kilos the explosion produced a pressure of 212.6 kilos. The time occupied by the explosion was, in this latter case, less than 2-100 of one second. The vessel in which the decomposition had occurred was found to contain carbon resembling lampblack, although in somewhat hardened crusts. Traces of graphite were detected in this carbon.

The heat of decomposition of acetylene being 51.4 calories, the temperature resulting from the decomposition will be theoretically about 2,750° C, and the pressure produced will be fully ten times the pressure of the original gas.

In an experiment tried with liquid acetylene, which half filled an indestructible steel vessel, the pressure developed was 5,564 kilos per square centimeter.

Berthelot concludes that the force of the shock developed by the sudden decomposition of acetylene is about equal to that of fired guncotton.

Experiments were tried in order to ascertain the effect of shock upon acetylene. A steel bomb of one liter capacity, containing 300 grams of gaseous acetylene under 10 atmospheres pressure, was subjected to blows from a weight of 280 kilos falling from a height of 6 meters. In other cases the cylinders were allowed to fall from the same height upon a steel anvil. No explosions were produced.

In similar experiments with liquid acetylene explosions occurred, shattering the bombs, but no trace of carbon was liberated. Berthelot explains this fact upon the supposition that the carbon set free was burnt by atmospheric oxygen after the breaking of the walls of the vessel. He further supposes that the minute quantity of air contained in the vessels sufficed to begin the combustion of the carbon, which was afterward completely burnt as the contents of the cylinder escaped into the atmosphere.

The ignition of other combustible gases, notably hydrogen, has been observed, when the vessel containing the gas under very high pressure, was broken.

Bullets, fired with sufficient force to penetrate the walls of the cylinders charged with acetylene, caused no explosion of the contents. It is Berthelot's opinion that shock produced by mechanical means alone will not directly cause explosion, although the striking together of metal parts, thrown by the bursting of a cylinder may cause ignition of the escaping gas.

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ERRATA SLIP.

To accompany paper by Mr. C. B. Murray, upon Methods of Analysis of Ores, Pig Iron and Steel, in use in the Laboratory of the Carnegie Steel Co., Ltd., Edgar Thomson Steel Works and Furnaces, Braddock, Pa.

Page 59, line 6 from bottom, "5 grams" should be "0.5 gram."

Page 64, line 3, "1700 c. c." should be 17000 c. c.

Page 64, line 16, "90° C." should be 40° C.

Paper read in April, 1896.

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Liquid acetylene is readily exploded by detonation of mercury fulminate, contained in a fine tube and inserted into the interior of the vessel.

High temperature is a possible cause of explosion of compressed acetylene.

The sudden heating which results when the gas is allowed to flow under pressure from one vessel into another may cause explosion of the acetylene in both vessels.

In the production of acetylene by the action of water upon calcium carbide local superheating may occur, tending towards explosive decomposition, especially when the gas is generated under pressure.

A conference of expert chemists was held on December 29th, 1896, in Berlin, at the call of Dr. Martius, Chairman of the Berufsgenossenschaft für Chemische Industrie, to discuss the subject of explosions of acetylene and their cause. ("Chemische Industrie," Feb., 1897.) At this conference the real nature of the danger was generally admitted.

Some of the more important opinions expressed may be summarized as follows :

Acetylene, as made from calcium carbide, is often contaminated with hydrogen phosphide and hydrogen sulphide. These impurities increase the tendency of acetylene to unite with copper, especially the phosphorus compound. The use of copper or brass valve fittings for the steel cylinders in which acetylene is stored may prove a source of danger, by reason of the formation of the explosive copper acetylide. (This opinion is by no means new.) It is important that the gas should be washed by passage through solutions of lead or copper salts, which serve to free it from such impurities before it is pumped into cylinders.

Inasmuch as calcium carbide has been known to glow as the result of the action of water, a danger occurs in the generation of the gas when large quantities of calcium carbide are used. Prof. Pictet, who conducts a factory for the manufac-

ture and liquefaction of acetylene in Paris, stated that explosions have been known to occur as a result of the heat generated by this reaction. Prof. Pictet at this meeting described the method of producing liquid acetylene at the Paris factory. The generator, in which the calcium carbide is decomposed by water, is kept cool by ice or a freezing machine. The crude acetylene is washed (1) by a strong calcium chloride solution, (2) by a solution of lead salt, (3) by sulphuric acid. All of these liquids are kept at a temperature of —16°C. After such treatment purification is considered to be complete. The gas is then compressed into vessels kept at a temperature of —20° by the evaporation of a mixture of sulphur dioxide and carbon dioxide. By means of tufts of wool the last of the moisture is removed and the gas is cooled to —80° C. by passage through a long coil of pipe, maintained at this temperature.

It is now pumped into cylinders kept at —80°, at which temperature a pressure of eight atmospheres suffices for liquefaction.

Acetylene so purified does not attack copper or other metals.

Pictet states that cylinders charged in his factory have been subjected to the most severe shocks (bullets were shot at them, they received heavy blows from large masses of iron, they were dashed against rocks, etc.), without causing explosion in a single case. Brass valve fittings are used in Pictet's cylinders.

The views expressed by Pictet at this conference concide with those of Berthelot. Both agree that mechanical shock cannot cause explosion of liquid acetylene, but it is admitted that should a rupture of the metal cylinder occur, from any cause, the escaping gas may become ignited by the heat due to the shock and a result simulating an explosion may occur.

At a meeting held in February, 1897, of the Nottingham Section of the Society of Chemical Industry, a report of which appears in the Society's Journal, 1897, p. 209, a discussion

took place as to dangers from acetylene Friction, due to rough handling of valves, and the presence of hydrogen phosphide in the acetylene, were there cited as potent causes of explosion.

In the factory of Julius Pintsch, in Berlin, a long series of experiments has been conducted with a view to testing the explosive properties of acetylene. (Journal für Gasbeleuchtung and Wasserversorgung, 1897, p. 201.)

In order to study the possibility of the production of metallic acetylides strips of metal were placed in cylinders charged with pure moist acetylene under ten atmospheres pressure, and these were left exposed to the extremes of summer heat and winter cold during nine months.

Of the metals tried, tin, nickel, aluminum and Britannia metal were unaltered. Lead was slightly corroded. Zinc, copper, brass, bronze, and aluminum bronze were strongly attacked. Chemical tests showed that acetylene compounds were not formed in any case. Neither hammer blows nor heat produced explosion of the coating formed upon the surface of the metal. Dry acetylene was found not to attack any of these metals, even in presence of ammonia. Corrosion of copper by a mixture of acetylene and ammonia is in reality due to the action of the ammonia alone. Similar negative results were obtained with brass and bronze. It is only when conditions exist favorable to the production of cuprous oxide that an acetylene compound can form.*

A cylinder of acetylene under six atmospheres pressure on being heated over a fire exploded violently.

In a similar experiment with a cylinder, closed by a fusible plug of tin, the gas escaped as the cylinder was heated to

* Keiser (American Chemical Journal, 1892, p. 290) states that metallic copper obtained by precipitation when suspended in water is converted by acetylene into the acetylide. Crova (Compts Rendus, L V, p. 435) has called attention to the occurrence of explosions of the acetylene copper compound on opening up the copper mains which were in former times used to convey coal gas.

the melting point of the tin (230° C) and burnt quietly without explosion. A cylinder of acetylene under a pressure of six atmospheres had connected with it a pipe of 1-5 inch bore. On heating the end of this (closed) pipe to 780°, the temperature of dissociation of acetylene, a violent explosion occurred in the cylinder.

Experiments were tried in order to ascertain to what extent an acetylene gas-holder would be exposed to danger of explosion in case a pipe leading from the holder into a house should be heated by the house taking fire.

It was found that so long as the gas-holder contains gas at atmospheric pressure the pipes leading from it may be heated to whiteness without danger of explosion.

In spite of some disagreements on the part of the authorities cited a summary of their views might be given as to the chief causes of danger from acetylene :—

1. The production of acetylene by the action of water upon calcium carbide is not wholly without danger where large quantities of the carbide are used. Its production under pressure is liable to cause local superheating and possibly explosion.

2. Gaseous acetylene under atmospheric pressure cannot under ordinary conditions be made to explode.

3. As the pressure increases beyond two atmospheres, the danger from explosion from all causes is enhanced.

Acetylene, under six atmospheres pressure, is likely to explode if heated to 780° C.

4. Neither gaseous nor liquid acetylene can be exploded by shock unless from the effects of the shock the containing vessel is broken, and then the heat resulting from an impact, or possibly a spark, may cause an explosion of the contents *en masse*. (The shock of the acetylene explosion in Pictet's factory did not induce explosion of other charged vessels standing near.) As regards the results, however, it would make very little difference whether the cause is to be looked for in the

shock, or in the heat produced as an effect of the shock, and it may be safely stated therefore that violent shocks of any kind might give rise to explosion.

5. Concerning the possibility of the production of the acetylene copper compound a difference of opinion exists. It seems probable that the views of Julius Pintsch are correct, and that the copper acetylide only results when copper is exposed to imperfect oxidation in presence of acetylene. In presence of dry acetylene, free from air, no such compound is likely to form.

6. Acetylene should be purified from phosphorus and sulphur compounds as far as possible before it is subjected to compression.

In view of the somewhat uncertain nature of the information concerning the causes of acetylene explosions, it is not surprising that the authorities and the insurance companies have been at sea in attempting to provide against risks of accident.

According to an order issued in December, 1896, by the police officials of Berlin, the production, liquefaction and storage of acetylene are to be subject to the same restrictions as are in force in the case of high explosives. (Jour. f. Gasbel. and Wasserv., 1897, p. 29.)

The rule has been adopted upon the German railroads that the steel vessels used to contain liquid acetylene for shipment shall be charged only to the extent of one-third of their capacity. In this way it is expected that the pressure developed in the case of an explosion will be lessened. (Journal f. Gasbel. and Wasserv., 1897, p. 152.)

The police officials of Paris have adopted strict regulations governing the manufacture and handling of acetylene.

In the United States the Underwriters' Association of the Middle District, have issued a circular, dated April 20th, 1897, agreeing to permit the use of acetylene by policy-holders, provided that vessels containing liquid acetylene and all pressure

regulators be kept out of the house. The same rule applies to acetylene generators and calcium carbide. The pressure of the gas in the pipes in houses must in no case exceed four ounces.

The wonderful light-giving power of acetylene, amounting to twelve times that of good coal gas, together with its freedom from poisonous properties, when pure, render it very desirable that means may be found for averting the dangers which have so far tended to impede its more general introduction as an illuminant.

After discussion of the paper by those present the Section adjourned at 9.45 P. M.

A. G. McKenna,
Secretary C. S.

STEEL ROOFS OF MILL BUILDINGS.

BY A. E. DUCKHAM, C. E.

It is not the author's intention to treat this subject in all its details, as the limited length of this paper will not permit it; but to simply investigate a few of the more important points connected with steel roofs according to the best practice of the present day. We will divide the subject according to the following heads: purlins, roof covering, and methods of figuring stresses.

Purlins. There seems to be no settled opinion as yet as to what is the best form of purlin to be used; each designer using that form which pleases him best, or which makes the easiest connection, or he uses that to which he has been accustomed. So we have some using an angle entirely; some prefer the channel; some will have nothing but an I-beam; some are in favor of a Z-bar; while some make use of a trussed purlin, regardless of span, pitch of roof, or other consideration. It is therefore largely the object of this paper to discuss the different forms as found in practice, and if possible decide upon that one which is found to be most efficient, scientific, and economical. And now to make a detailed examination of the different forms in use.

Angle Purlin. This may be set with the leg resting flat on the rafter as shown in the illustration at *a*, fig. 1; or, as is better and more usual, with one leg riveted or bolted to a lug angle, as at *b*. The latter method affords more bearing and gives a better "clip" connection for the corrugated iron, when it is used resting directly on the purlins, as is usual in mill buildings. We will first investigate a purlin for a 12-foot bay which is about right for trusses of 50-foot span (viz., a little more than one-fifth the span). The load assumed for the trusses will be 40 pounds to the square foot horizontal projection, or 30 pounds per square foot for the purlins. The distance between purlins will be taken as 5 feet (a distance of

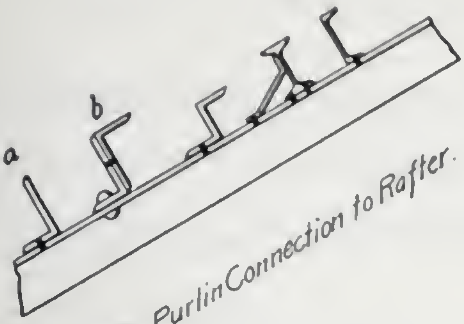


Fig1 Purlin Connection to Rafter.

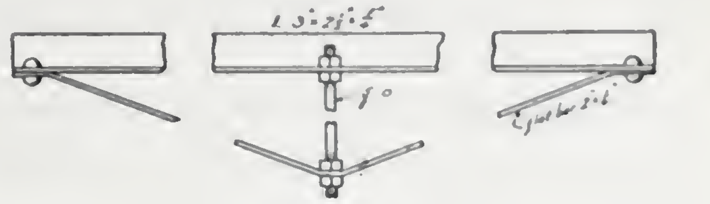


Fig 2

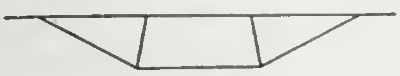


Fig 4

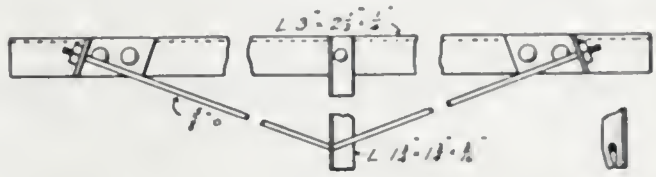


Fig 3.

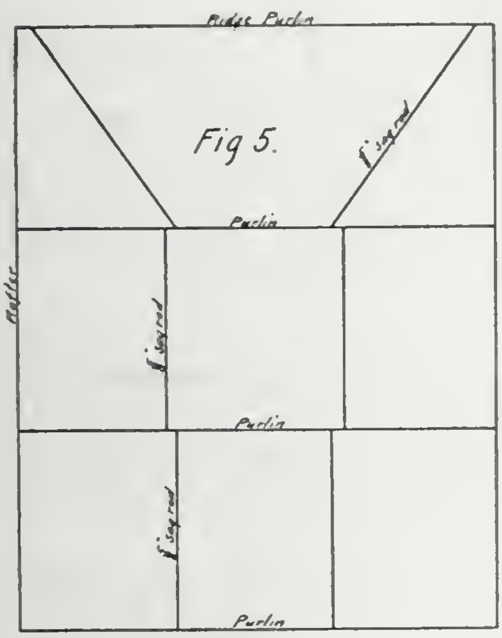


Fig 5.

Fig 6

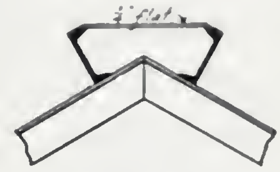


Fig 7.

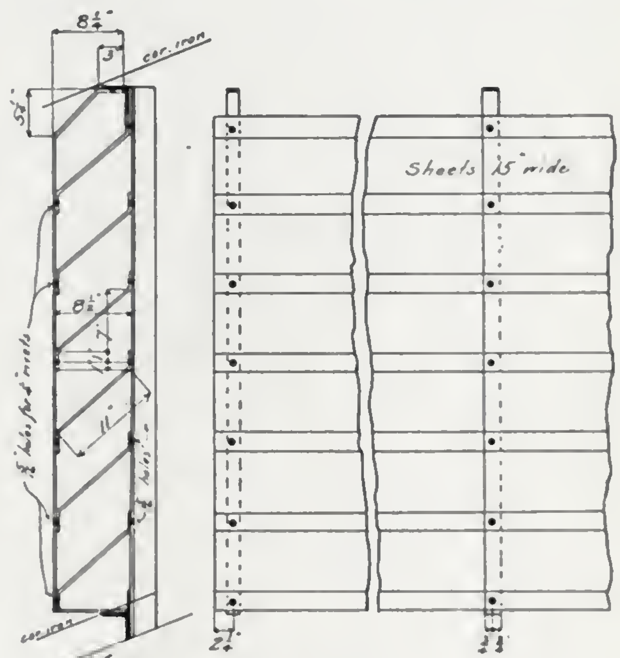


Fig. 8

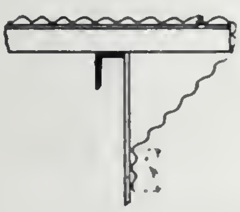


Fig 9

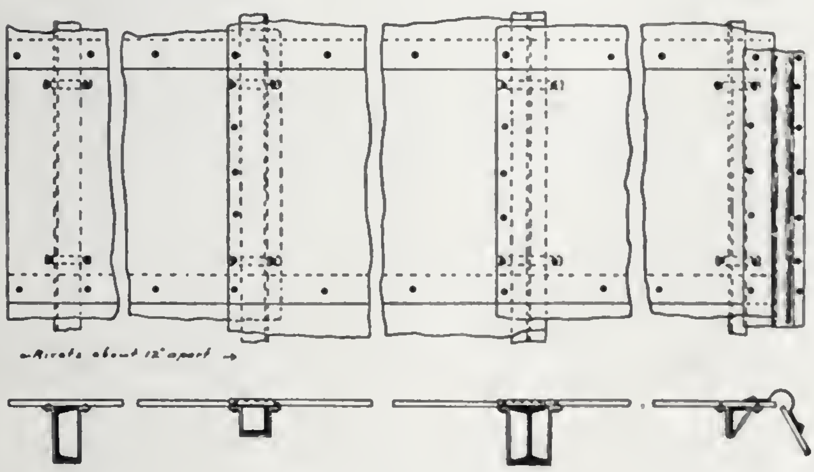


Fig.10

SHEET 1.

6 feet should not be exceeded for No. 20 corrugated sheathing). Then the load on one purlin will be $5 \times 12 \times 30 = 1,800$ pounds. The bending moment for a beam uniformly loaded being $\frac{Wl}{8}$ (where W=total load and l=span), we have $\frac{1800 \times 12 \times 12}{8} =$ 32400 inch pounds. Allowing 1600 for unit strain, we have $\frac{32400}{16000} = 2.025$ as the value of S="Section modulus" (formerly known as the "moment of resistance") of "Carnegie's Pocket Companion." Looking for the nearest value of S in the "Properties of Angles," we find 2.21 for a $5 \times 3 \times \frac{3}{8}$—9.8 lbs. angle with a 5 inch leg vertical, which angle will be the correct one to use for this span.

The I-beam Purlin.—Using the above values we find the nearest value of S in the Properties of I-beams corresponding to our calculated value of 2.02 to be 3.0, which is for a 4 inch I—7.5 lbs.—web vertical.

The Channel Purlin.—Here we have S required=2.02. The nearest S found in "Properties of Channels"=2.1, which is for a 4 inch channel, 6.25 lbs., web placed vertically.

The Z-bar Purlin.—S required being as before = 2.02, we have for a $3\frac{1}{16}$ inch Z—$\frac{5}{16}$ inch metal 8.4 lbs., S=2.38. We thus see that, according to weight, the channel is most economical; next comes the I-beam, then the Z-bar, and lastly the angle.

Should we desire to take into account the deflection of the purlin, we have from "Carnegie's Pocket Companion," on page 76, $\frac{152.5}{4} = 38$ or $\frac{38}{64} = \frac{19}{32}$ inch for the I or channel, $\frac{152.5}{3} = 50$ or $\frac{50}{64} = \frac{25}{32}$ for the Z, and $\frac{152.50}{1.68 \times 2} = 45$ or $\frac{45}{64}$ for the angle. Of course we must remember that this deflection is for a beam not fastened or fixed at the ends. The purlins being bolted or riveted to the rafters of the trusses, this deflection will be considerably reduced.

Next taking up a 16 foot bay (say for a 60 foot roof span). Loading being as before, $16 \times 5 \times 30 = 2,400$ lbs. on each purlin. Maximum bending moment $= M = \frac{Wl}{8} = \frac{2,400 \times 16 \times 12}{8} = 57,600$ inch lbs. $\frac{57,600}{16,000} = 3.6 =$ the required value of $S =$ Section Modulus. A $6 \times 4 \times \frac{7}{16}$—14.3 lbs. angle will be selected, its S being 3.80, 6 inch leg vertical. If we look for an I-beam, we find that a 5 inch I—9.75 lbs. answers the requirement, S being 4.8. A 5 inch channel, 9 lbs. next will be chosen, S being 3.5. Or a $4\frac{1}{16}$ inch Z-bar—10.3 lbs. gives us $S = 3.91$. The corresponding deflections of the various shapes were found in the same manner as before to be as follows: Angle $= 1\frac{1}{16}$ inch, I-beam $= \frac{27}{32}$ inch, channel $= \frac{27}{32}$ inch, Z-bar $= 1\frac{1}{16}$ inch (purlin assumed as not fixed at ends).

Assuming now a 20 foot bay (for probably an 80 or 90 foot roof span), and figuring as before, $20 \times 5 \text{x} 30 = 3,000$ lbs. = load on one purlin. $M = \frac{Wl}{8} = \frac{3,000\text{x}20\text{x}12}{8} = 90,000$ inch lbs. $\frac{90,000}{16,000} = 5.62 =$ required value of S. A $7\text{x}3\frac{1}{2}\text{x}\frac{9}{16}$—19 lbs. angle most nearly fits the case, its S (7 inch leg vertical) being 5.79. Its deflection $= \frac{423.7}{2\text{x}2.5} = \frac{84}{64}$ inch $= 1\frac{5}{16}$. A 6 inch I-beam—12.25 lbs., gives us $S = 7.3$ with deflection of $\frac{424}{6} = \frac{70}{64}$ inches $= 1\frac{3}{32}$ inches. A 7 inch channel—9.75 lbs., will give $S = 6.0$, with a deflection of $\frac{424}{7} = \frac{60}{64}$ inch $= \frac{15}{16}$ inch. A $5\frac{1}{16}$ inch Z-bar, 13.9 lbs., has $S = 6.39$, and a deflection of $\frac{424}{5} = \frac{84}{64}$ inches $= 1\frac{5}{16}$.

Supposing that we wish to use a trussed purlin. Taking a single strut, or king-post style, and finding the strains, we proceed as follows: Assuming the tie rods screwed up until

the top of the posts is on a level with the ends of the purlin; then P (= compression in post)$=\frac{5}{8}$ W, and T (=tension in tie-rod)$=\dfrac{P'}{2 \cos a}$ (a being the angle between the post and the tie-rod) $=5\text{-}16 \dfrac{W}{\cos a.}$ At each support the horizontal component of T=C=T sine a=5-16 W tan a. Assuming a 12-foot span, and referring to our previous work, the load on one purlin= 1,800 pounds. Then substituting in our formula: $P=\frac{5}{8}W=\frac{5}{8}\times 1800 = 1130$ pounds, $T=5\text{-}16 \dfrac{W}{\cos a} = 5\text{-}16 \times \dfrac{1800}{.317} =$ 1780 pounds, C=5-16 W tan a=5-16×1800×.333=1690. Figuring the bending moment for the half span (or the portion of purlin between the post and the end), we have $M=\frac{1}{8} W'l'=\frac{1}{8}\times 900\times 6\times 12=8100$ inch pounds.

Having our stresses, we will now take up a simple design shown in Fig. 2 of sheet 1. The required area of the tie$=\dfrac{1780}{18000}=0.1$ square inch. Assuming a $2\times\frac{1}{4}$ flat bar with an area of 0.5 sq. in.; and deducting 3-16 sq. in. ($\frac{3}{4}\times\frac{1}{4}$) for the hole we have $\frac{1}{2}$—3-16=5-16 sq. in. effective area, which is more than sufficient. The required area of the post $=\dfrac{1130}{5000}=$ .226 sq. in. area. We will use a $\frac{5}{8}''$ round bar=.307 sq. in. area. For the half purlin, investigated as a beam, $\dfrac{8100}{16000}=$ 0.5=required "section modulus." From "Carnegie," an angle $3\times 2\frac{1}{2}\times\frac{1}{4}$—4.5 lbs. has S=.56. The total weight of the purlin will be 76.5 lbs., or 6.4 lbs. per foot.

If we take another design, as shown in fig. 3, and using the data already found, we have the following: Taking a $\frac{5}{8}''$ round bar=.307 sq. in. area for the tie, there will be three times the area required. Then with a $1\frac{3}{4}\times 1\frac{3}{4}\times$3-16 angle for the post=.62 sq. in., area required$=\dfrac{1130}{8000}=$.14 sq. in. The

horizontal portion of the purlin will be as before a $3\times2\frac{1}{2}\times\frac{1}{4}$ angle. The tie will be connected to it by $5\times3\times5$-16 angles as shown in fig. 3. The weight of the purlin will be about 68 lbs., or 5.7 lbs. per foot.

Next, supposing a 16-foot single strut trussed purlin be taken, we have the following strains in pounds deduced as previously shown: P=1500, T=2370, C=2250 pounds, and M=14400 inch pounds. With the design of fig. 2, $\frac{1500}{4300}$ = .35 sq. in.; use a $\frac{3}{4}''$ round=.44 sq. in. for strut; $\frac{2370}{18000}$ = .13 sq. in.; use a $2\frac{1}{4}\times\frac{1}{4}$ flat bar for tie: $\frac{14400}{16000}=0.9=S$ required; S=0.96 for a $3\frac{1}{2}\times3\times5$-16—6.6 lbs. angle for the beam. Weight of purlin, 118 lbs., or 7.4 lbs. per foot.

If we intend to use a queen-post truss (two struts) as in fig. 4 (shown in skeleton), we have the strains as follows: P=880, T=2790, C=2640 pounds, M=6400 inch pounds. Then the area of the tie required $=\frac{2790}{18000}=.16$; that of the struts $=\frac{880}{4400}=.2$. So we will use for the former a $2\frac{1}{4}\times\frac{1}{4}$ flat, and for the latter a $\frac{3}{4}''$ round (=.44 sq. in. area). For the horizontal part at top (or top chord of truss) $S=\frac{6400}{16000}=.4$: we will use a $3\times2\times\frac{1}{4}$—4.0 lbs. angle, whose S=.54. Then the weight of the purlin=104 pounds, or 6.5 pounds per foot. So we see that by using a queen-post instead of a king-post truss we decrease the weight, but necessarily increase the shop work slightly. Care must be taken that the struts in the queen-post truss bisect the angle at their intersection with the lower chord; especially in those of the design of fig. 3, there being but one rivet at the upper chord to prevent the strut from turning.

The strains for a 20-foot king-post trussed purlin will be as follows: P=1880, T=2970, C=2820 pounds, and M=

22500 inch pounds. Using the same design as fig. 2, we have $\frac{1880}{4300}=.437$ sq. in., and we will use a $\frac{3}{4}''$ round$=.44$ sq. in.; also $\frac{2970}{18000}=.16$ sq. in. required, and a $2\frac{1}{4}\times\frac{1}{4}$ flat used; again, $\frac{22500}{16000}=1.4=$required S, and use a $4\times3\frac{1}{2}\times\frac{3}{8}$—9.1 lbs. angle, whose value of S$=1.5$. The weight of the above purlin$=9.9$ lbs. per foot. If we design a purlin for this span as illustrated in fig. 3, we have the following sections for the strut and tie: take a $2\text{x}2\text{x}\frac{1}{4}$—3.2 lbs. angle for the strut, area $=.94$ sq. in., while the area required is only $\frac{1880}{7000}=.21$ sq. in.; for the tie as before .16 sq. in. is required, but a $\frac{3}{4}$ in. round will be used, area$=.44$ sq. in. in the main part of bar, but which is reduced by the screw thread at the ends to .31 sq. in. This purlin will weigh 11 pounds per foot. If we were to use the same design, but substitute a queen-post truss (fig. 4) instead of the king-post, we would have the following results: For the stresses, we have P$=1100$, T$=3480$, C$=3300$, M$=$ 10000 inch pounds. Then $\frac{1100}{7800}=.14$ sq. in.$=$area required for the struts; a $1\frac{3}{4}\text{x}1\frac{3}{4}\text{x}\frac{1}{4}$–2.8 lbs. angle, area$=.81$ will be used. Also $\frac{3480}{18000}=.19$ sq. in., area required for the tie; a $\frac{3}{4}$ inch round, area$=.44$ (or .31 area at screw ends) will be used. For the upper chord of the purlin we will use a $3\frac{1}{2}\text{x}2\frac{1}{2}$ $\text{x}\frac{1}{4}$–4.9 lbs. angle, S$=.75$; for $\frac{10000}{16000}=.62=$S required. The weight of the purlin will be 7 pounds per foot (total weight$=$ 140 pounds). The queen-post truss for this span is therefore more economical.

If we now take a retrospective view of these different forms of purlins, we will see that for bays from 16 to 20 feet or more a trussed purlin is lighter than a simple beam, and

furthermore that a queen-post is lighter than a king-post. As a matter of practice, when the extra cost of punching, riveting, bending, etc., is taken into account, for the few pounds difference in weight perhaps the beam purlin is as cheap as the trussed purlin. The beam purlin, with the exception of the channel, is stiffer with respect to the component of the force acting in the plane of the roof than the trussed purlin. But this difficulty may be overcome by using "sag-rods" in the plane of the rafters. as shown in fig. 5. If the "sag-rods" extend straight up, instead of being inclined at the ridge purlin as shown in fig. 5, they may be supported as in fig. 6 or fig. 7. The purlins need bracing in this plane to prevent the sheathing from being torn from the nails or clips.

Supposing we investigate a channel purlin for a 16-foot bay, with regards to this latter force, which purlin we have before found to be a 5″ channel, 9 lbs. As there is no value for the "section modulus" in this position given in the tables, we will calculate the value of the unit strain per square inch according to the regular formula of mechanics, viz: $M = f\frac{I}{n}$ (the nomenclature being that given in Carnegie's "Pocket Companion" on page 101), or $f = \frac{Mn}{I}$. From the table of "Properties of Channels," however, we have $I = 0.64$, and $n = 0.48$. Also we know that $M = \frac{Wl}{8}$. To find W, we take for example a roof having $\frac{1}{4}$ "pitch;" hence the "bevel" = 6 in 12 or $\frac{1}{2}$ in 1; consequently, if the normal force on the roof is 30 pounds the force parallel to the roof = 15 pounds, and $W = 16 \times 5 \times 15 = 1200$. Then $M = \frac{1200 \times 16 \times 12}{8} = 25200$ in. pounds. Substituting this in $f = \frac{Mn}{I}$ we get $f = \frac{25200 \times .48}{.64} = 18890$ lbs. which shows that the purlin is not strong enough to stand unsupported in this direction, but will need the support of sag-rods.

Roof-Covering.—This, on mill-buildings, boiler-houses, coal-tipples, etc., is usually corrugated iron laid directly on the purlins; or, in some cases, to prevent condensation of moisture in the atmosphere, which in case of machine-shops might injure the machinery beneath, it is laid on board sheathing. There is also an "anti-condensation" corrugated-iron covering used by an Eastern Bridge Company on their buildings. By this method the purlins are spaced about 27 inches apart, while upon them is laid galvanized wire netting. Upon this two layers of asbestos-paper are placed. Then on top of this we have two layers of tar-paper. Upon all this the corrugated-iron is laid. The asbestos-paper renders the roof fire-proof, and the tar-paper prevents moisture going through, if any should condense on the under side of the corrugated-iron.

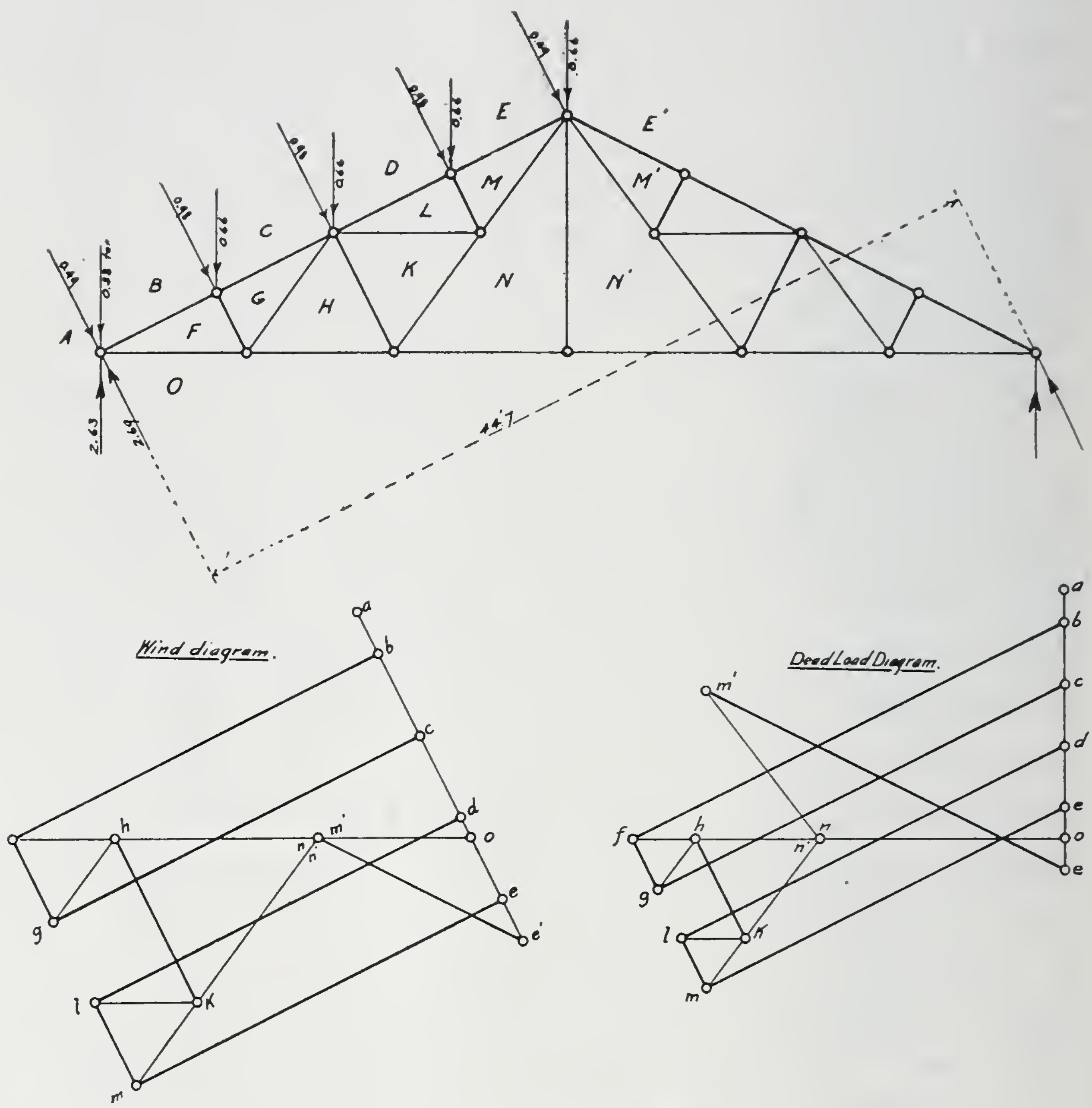
The corrugated-iron generally used for roofs is No. 20, and for the sides No. 22. The usual covering width is from 24 to 26 inches. The usual lap is 1½ corrugations on side, 6 inches on end for roofs; and 1 corrugation on side, 4 inches on end for siding. The length of sheets vary from 5 to 10 feet—foot lengths being in stock at the mill. The corrugations are generally 2½ inches apart.

The "clips" used to fasten the corrugated-iron to the purlins are usually No. 18 hoop-iron, ¾ inch wide. They are fastened around the purlins as shown in Fig. 10. A bundle weighs 100 pounds, and contains 800 feet. In ordering we allow one clip per foot of purlin or girt. The clips are about 12 inches long for angle supports. The rivets are 3-16 inch diameter, the heads are flat, with burs, and galvanized. The lengths are ⅝ inch on sides and ends of sheets, ½ inch on corners of sheets and clips, for Nos. 20 to 24. We order 8 long and 7 short per bottom sheet, 6 long and 9 short per top sheet, 5 long and 9 short per intermediate sheet, 6 short per foot of "ridge-roll," and 2 short per foot of cornice. The ridge-roll may be made from a 15 inch sheet—5 inch apron, and 3 inches across roll. The rivets are driven cold, one man standing un-

der the roof holding the clip and rivets in place, while another on top punches the holes and drives the rivets. The corrugated-iron may be galvanized, painted, or both. One gallon of thick paint in cold weather will cover from 400 to 500 square feet; one gallon of thin paint in warm weather will cover 600 to 700 square feet. The method of connecting the purlin to the rafter is shown in Fig. 1. As shown, if the pitch of the roof is great, the I beam purlin is braced by a bent plate. The corrugated-iron at the sides of the building should not project too far (about one foot will do), as the wind is liable to tear it loose. At the ends of the building it is bent over and fastened, as shown in Fig. 9. A system of sheet iron "louvres" (generally No. 18) for the "ventilator" of a mill building is shown in Fig. 8. The drawing is self-explanatory.

Before leaving the subject, we will devote a small space to the subject of the strains in the roof-trusses, particularly as regards the different assumptions of loading and directions in which the forces operating act. Suppose we have for example a Fink roof-truss of 50 foot span, pitch $\frac{1}{4}$, and the trusses are 12 feet apart. Then assuming as the load per square foot of roof-surface the following: dead load, 16 lbs.; (iron$=$6 lbs., and slate on $1\frac{1}{4}$ inch boards, 10 lbs.); snow and wind, 30 lbs.; making a total vertical load of 46 lbs. Then the apex load (or load at each joint of the roof) $= 46 \times 12 \times 7 = 3{,}860$ lbs., $= 1.93$ tons, (the rafter being 28 feet long). Now using the table of coefficients, as given in Johnson's "Modern Framed Structures," with one setting of the slide-rule we quickly obtain the following stresses (see truss diagram of sheet 2 for notation): BF$=$15.5 tons, FO$=$13.5, FG$=$1.72, CG$=$14.2, GH$=$1.93, HO$=$11.6, HK$=$3.47, DL$=$13.4, LK$=$1.93, NO$=$7.72, KN$=$3.86, LM$=$1.72, MN$=$5.79, EM$=$12.25.

But, taking the more exact method of dead and snow load vertical and wind load normal to the roof surface, we deduce the following: The snow is taken as weighing 15 lbs. per square foot of horizontal surface; and the wind is assumed as



SHEET 2.

exerting a horizontal pressure of 40 lbs. per square foot, or for this angle of roof the normal pressure on the roof is 23.8 lbs. Then by graphics, as shown on sheet 2, we find the dead load (truss and roof-covering) first, and by proportion (and the slide-rule) we get the snow load (as both act vertically). Only half of the force diagram for dead load is shown, as the stresses are symmetrical about the center of the truss. The dead load at each apex is .66 tons; snow load at each apex .55 tons, and the wind apex load is 0.98 tons—all acting in the direction shown in diagram. To get the wind reaction, a-o, we take moments with the other end of the truss as a center: thus, AO x 44.7 — 0.49 x 44.7 — 9.8 x 37.7 — 9.8 x 30.7 — 9.8 x 23.7—0.49 x 16.7 = 0. AO = 2.69 tons. We notice that there is no stress for the wind load on the left side of the roof in N′ M′, while there is a stress of 2.45 tons in E′ M′. The scale for the skeleton truss (on the original drawing) was 5 feet to 1 inch, and for the stress diagram 1 ton to 1 inch. Herewith is appended a table showing the stresses in each member due to dead, snow and wind load, also the maximum stress:

STRESSES IN 50 FOOT FINK TRUSS.

Member.	Dead Load.	Snow.	Wind.	Max.
BF	—5.17	—4.29	—4.38	—13.84
FG	—0.60	—0.50	—0.98	— 2.08
GN	+0.68	+0.56	+1.10	+ 2.34
CG	—4.88	—4.05	—4.38	—13.31
HK	—1.18	—0.98	—1.95	— 4.11
KL	+0.68	+0.56	+1.09	+ 2.33
DL	—4.58	—3.80	—4.38	—12.76
LM	—0.60	—0.50	—0.98	— 2.08
EM	—4.29	—3.56	—4.38	—12.23
MN	+2.00	+1.66	+3.27	+ 6.93
KN	+1.33	+1.10	+2.17	+ 4.60
FO	+4.63	+3.84	+4.88	+13.35
HO	+3.95	+3.28	+3.80	+11.03
NO	+2.62	+2.17	+1.63	+ 6.42
NN′	0.00	0.00	0.00	0.00

NOTE.—Stress given in tons. — indicates compression, and + tension.

Now, comparing these stresses with those found previously by the single vertical load—resolving the wind apex load, 0.98 tons, into its components, we find the vertical load to be $0.98 \times \cos. 26° 34' = 0.98 \times .894 = .88$ tons. This, added to the snow load, 0.55, and the dead load, 0.66, gives us 2.09 tons as the total vertical load. Comparing this with the first assumption of a single vertical load, we find that we had there an apex load of 1.93 tons : so that the loads being almost the same, we can easily compare the stresses as found. We find that in the chords the stresses are greater for the combined loading, though the apex load is less ; while in the web the opposite is the case. In conclusion, the author of this paper believes that it is better, for the slight additional work, to figure the stresses in that manner which approaches nearest to that occurring in nature ; and it is his opinion that that result is most nearly reached by the system of separate forces, as last shown (the wind acting on but one side of the roof, and normal to it).

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the rooms of the Society's House, 410 Penn Avenue, Pittsburg, Pa., Tuesday evening, June 15th, '97, the President, Mr. Emil Swensson, being in the chair. The meeting was called to order at 8.10, 29 members and visitors being present.

The minutes of the previous meeting were read and approved.

It was voted that the discussion of the new constitution be held over until after the summer vacation.

The chairman, Mr. E. K. Morse, of the committee on the Dalzell Bill being absent, a member reported "that he understood that the Bill would not come up at this session of Congress, and that when it does come up Mr. Dalzell will inform your committee in time to appear before the proper committee at Washington. Mr. Dalzell has written to that effect, and he will give our committee all the attention that we think will be needed."

Mr. Davison reported for the committee on new charters, "that this committee does not get the same attention at Harrisburg that the other committee gets at Washington. There seems to be a few people who are really in earnest, that are behind the reform charter, but we seriously doubt whether there are any members of Legislature who are, and doubt whether we shall be able to do anything, because we doubt whether anything will come of these charter bills, as we believe they are being used simply for political purposes. We have written certain members of the Legislature, but have had no reply and no one seems to be in earnest about it."

The chairman of the Reception Committee, Mr. Engstrom, being absent, Mr. Wilkins reported that notices for a meeting of the committee had been sent out and that only two members had responded, but that Mr. Engstrom had the matter of arranging for the boat and music in hand, and they would be attended to.

The President then read a communication received from the Illinois Society of Engineers and Surveyors, on the "International Metric System of Weights and Measures," and remarked that, although he did not think this matter would come up at this session of Congress, he would like to have some remarks on the circular.

After some discussion by Messrs. Diescher, Crooker and some remarks made by the President, it was voted that the matter be laid on the table and taken up after vacation.

Mr. Fisher reported for the Power Committee that they had sent to the members of this Society a list of questions and a circular letter, which they proposed sending to the different manufacturers in the city, and as it would be somewhat difficult to send the questions and letters to the right persons, he would ask the members of the Society to send to the committee a list of persons or firms, whom they knew had made careful tests of their plants; who had gone into the matter and knew the actual cost of power, or of any persons who were likely to make such tests.

Mr. A. E. Duckham then read the paper of the evening, entitled "Steel Roofs of Mill Buildings." Pages 310 to 323 of Proceedings. After a discussion of the paper the meeting adjourned.

Reginald A. Fessenden,
Secretary.

MEETING OF THE CHEMICAL SECTION.

Pittsburg, Pa., June 17, 1897.

The regular monthly meeting of the Chemical Section of the Engineers' Society of Western Pennsylvania, was held in

the lecture room of the Society's House, 410 Penn Avenue, Pittsburg, Pa., June 17th, 1897.

In the absence of a quorum no business was transacted.

A. G. McKenna,
Secretary C. S.

THE DEVELOPMENT OF THE AMERICAN BLOOMING MILL.

BY RALPH CROOKER, JR.

The Bessemer and Open Hearth processes are the survivors of many attempts to produce a cheaper or better material than that produced by puddling.

When these new methods of working iron emerged from the wholly experimental stage and became accepted commercial facts, they found the iron and steel industry already in a highly developed state. The crucible steel process was then about as perfect as it is to-day; while the making of puddled iron, stimulated to the highest degree by the building of railroads—which it had made possible—had reached a point which it has since excelled but little, if any, in quality; although for some years afterwards it continued to increase in quantity.

It was to the machinery prepared for the handling of these materials—crucible steel and wrought iron—that the first ingots of the new processes—at first almost exclusively Bessemer—came, to be worked into the shapes that afforded the best market for them, or which stood most in need of such improvement in quality as they offered.

In England, where the greater part of the early development of the Bessemer was done, the ingots were at once sent to the hammer, and submitted to the same treatment as the crucible steel. I am unable to find that any attempt was made to roll it direct from the ingot during the first few years of Bessemer practice; a fortunate circumstance, I think all will agree, who are familiar with the characteristics of that early

steel. The product of an English Bessemer works at this time—the middle sixties—was so small—from one to two hundred tons per week—and relatively of so little importance in the large English and continental works, that the need of machinery especially to care for it does not seem to have been felt. It was a very simple matter to add hammers as the product of the Bessemer works increased, which it did very rapidly, and this was the universal practice, persisted in until the forge department of some of the works attained tremendous proportions, one firm alone having seventy hammers in use before abandoning the system, and making little or no change except to strengthen them and increase the size from four to five, and then to seven and ten tons.

The first to undertake the improvement of this state of affairs was Mr. John Ramsbottom. He undertook to improve the hammer itself, and brought out his duplex hammer, which consisted of two hammer heads moving horizontally towards each other on rollers, the heads being actuated by a steam cylinder through links, the ingot worked upon being placed between the hammer heads, and moved in a direction at right angles with their motion.

Several of these were put in operation, but they do not seem to have altogether accomplished their purpose, at least they do not seem to have suited Mr. Ramsbottom, for he shortly afterwards introduced his cogging mill, which was one of several devices brought forward at about the same time by different inventors, and the only one of them, so far as I can ascertain, which was ever put in practical use.

This mill in its general features was so nearly like the later blooming mills that one wonders how he managed to miss it. It consisted of a pair of huge housings carrying a pair of arbors, to which were bolted segments of cast iron, forming grooves which went part way around the rolls. The two rolls were made to turn in unison by means of pinions keyed to their necks and were driven, through very high gear-

ing, by a small reversing engine. The top roll was counter-balanced by a small hydraulic cylinder in the window of the housing between the necks—an arrangement made possible by the great diameter of the rolls—over five feet—and the top roll was forced down by a wedge, driven between the top of the housing and the top box by a hydraulic cylinder, operating through a rack and pinion. The vertical movement of the top roll with this arrangement was, of course, very limited.

While Mr. Ramsbottom was busy trying to correct the faults of his duplex hammer, by building his cogging mill, others, who were using them, were wrestling with the same problem, which was forced upon them by the constantly increasing output of their Bessemer works; and the obvious methods of rolling the ingots in the "top and bottom" rolls of their rail mills was tried by several, and with considerable success.

With the English rail mills it was an easy matter to do this, and it may be well here to call attention to the distinct difference in practice existing between the English and American mills of the period (1867), a difference which had come about during the preceding ten years.

Up to 1857 the mills for heavy work—those in America being nearly all rail mills—were the same in both countries, too high and non-reversing, the piece being returned over the top roll. In this year Mr. John Fritz first put in use his hanging guide, which made three-high rail mills possible, and within a few years all the American mills were made three-high.

This was not the case in England, however, where efforts were made to improve their two high mills by reversing the motion of the rolls between passes, so as to work the piece through the rolls in both directions, the means adopted being five gears and a clutch—many kinds of which were used—and later, reversing engines.

So at the latter end of the decade between 1860 and 1870 the universal practice in America was three-high and in England reversing two-high mills.

It is not surprising, therefore, that in its first blooming mills each country should have followed the form of mill prevailing at home; but so fixed was the difference of opinion as to their respective merits that each country stuck to its own, without a waver, for the next ten years, and without, seemingly, caring to know much about the other.

When it was shown that ingots could be bloomed successfully on the "top and bottom" rolls, larger reversing mills, built especially for the purpose quickly followed, and several were in use at the end of the decade (1860–1870), although hammering was continued in some works for many years.

America did not begin its modern steel making as soon as England and Europe, nor did it advance so rapidly for some time after it began. There were several reasons for this. We were busy with a great war, which absorbed all our energies, most of our money and many lives, costs of installation and production generally were much greater, and uncertainty and dispute as to patent rights made it hazardous to enter upon such undertakings, so it was 1864 when the first ingots were made at Wyandotte and they, like those produced abroad at the same time, were hammered. Troy, Pennsylvania, Freedom and Cleveland, the only other producers of Bessemer steel in that decade, all used the hammer for blooming.

It was at the beginning of the decade (1870–1880) when the production of Bessemer steel ingots in America had reached 40,000 tons for the year, that the shortcomings of the hammer began to be seriously felt, and the necessity of building blooming mills forced itself upon the steel makers of this country, and the first works to put a blooming mill in operation was Troy, which rolled its first ingots in January, 1871. This mill, following the general practice of

American rolling mills, was a three-high mill, being the first three-high blooming mill in the world, as well as the first blooming mill in the United States. Its top and bottom rolls were fixed, the middle roll was carried in a pair of forged steel bolsters and was moved up or down after each pass by four screws driven from the main engine shaft by a belt, shafting and worm gearing controlled by a belt-driven reversing clutch. The tables on both sides of the rolls were raised and lowered together by hydraulic power. The top of the tables was made up of loose rollers, spaced closely, and on these the two rail ingots were pushed straight for the passes and into the rolls with bars and turned with tongs.

About six months later (July 10, 1871) the Cambria Iron Co. put in operation a mill designed by Mr. George Fritz, which had much the same influence on American blooming mills as his brother's earlier invention had had on American rail mills, and fixed the type of mill in almost exclusive use for the decade. This, also, was a three-high mill; but it differed from the Troy mill in having its middle roll stationary, while the top and bottom rolls were movable. The top roll was counterbalanced and the top and bottom rolls were moved towards the middle one between passes by screws acting together; they were, therefore, only obliged to make the full travel when opening to receive the ingot for the first pass.

The important feature, however, was the tables. These raised and lowered together by hydraulic power, and the tops were composed of rollers arranged to be driven from the main engine by gearing controlled by friction clutches. Combined with this was a manipulator, which consisted of a small car beneath the table with prongs on top of it, extending up through the table rollers when the table was down; this car was moved transversely to any desired position under the table by a hydraulic cylinder, and by lowering the ingot on to the prongs it could be turned, or by pushing the prongs against the side of the ingot it could be moved from pass to pass. This mill was a notabte success.

The next year (1872) the Cleveland Rolling Mill Co. built a blooming mill which deserves mention as the first reversing blooming mill built in this country and also because it was the only one of its type ever constructed here. It was a clutch reversing mill and all the auxiliaries, tables, shears and shear tables were driven from the train engine. As at first put down it reversed with a three-gear clutch; this was afterwards changed to the five-gear system. In both cases friction clutches were used, and I believe that no blooming mill has ever been built here that reversed with crab clutches. English practice largely influenced the design of this mill and at that time the superiority of reversing engines was not established—although it surely was shortly afterwards; but that friction clutches were better than crab clutches for reversing was settled. The engineering periodicals and the records of engineering societies for some five or six years about 1870, are full of illustrations and discussions as to the relative merits of the many devices proposed to overcome the glaring faults of the crab, and are interesting history.

These three mills (Troy, Cambria and Cleveland) may be grouped as the pioneer American blooming mills; but the "Fritz" mill only needs further attention, the others having had no influence whatever on the design of later mills.

If the manufacture of Bessemer steel in America made slow progress in the decade 1860-1870, it quite made up for it in the first half of the next, eight large works being built on much improved plans. These were all intended for the manufacture of rails, and hardly any other outlet for their product was looked for or expected, the power of new railroad enterprises to absorb the product seeming, at the time, to be almost limitless, while the inferior quality of much of the early steel still cast a deep shadow of suspicion on its reliability for other purposes.

For blooming ingots, of the size then made for rails, it was, and is still difficult to improve on the Fritz mill; the size

of the ingots not requiring excessive length of tables and the large section of the finished bloom made it possible to do the work on short rolls of comparatively small diameter.

Under these conditions it is easy to understand why nearly all of these eight works, built between 1871 and 1876, put in "Fritz" blooming mills, and no other kind of mill had a trial until these conditions changed.

As these mills followed each other in rapid suscession, each was an attempt to improve upon its predecessors; but the improvements were entirely confined to minor details. Driving the tables by independent power succeeded various methods of driving from the main engines, operating the table rollers automatically by V friction wheels, engaging when the tables where in either the highest or lowest position, came into use and was followed by a positive drive by means of gears, lazy tongs and reversing engines; the rolls, however, continued to be movable.

The great expansion of the Bessemer steel rail business between 1871 and 1876 was followed by an equally great depression in consequence of the business panic of 1873, and during the last half of the decade very little was done in new Bessemer construction, the efforts of the steel makers being entirely directed towards economical production, and it was these efforts which led to the first departure from what had come to be distinctly recognized as the American blooming mill.

The familiar method of increasing the tonnage was the one almost universally adopted to bring about the desired result, and so successful were the managers of the converting departments in this direction that the product of vessels soon exceeded the capacity of the casting pits to handle it, planned, as they had been, for the work of some years earlier.

Faced with this state of affairs the Cambria Iron Co., in 1878, determined on a radical departure from the prevailing pit practice, which involved the making of ingots much larger than those in common use, and to care for these they put in a

mill which deserves attention, being the first blooming mill in the country reversing with engines, and unique in other respects.

When the "Freedom" works was built in 1868 a plate mill had been imported from England with a reversing engine, said at the time to be "the best of its class yet produced." It was this mill and engine, with blooming rolls substituted for the original plate rolls, which the Cambria Iron Co. utilized to work the large ingots. It was, therefore, an English mill; but the tables, which constituted its chief title to distinction, were American, having been designed by the late Mr. Daniel N. Jones. These consisted of large rectangular frames carrying the gudgeons of loose rollers, the bodies of which rested on solid tracks. These frames, with the rollers, were moved to and from the rolls, through a short distance, by hydraulic cylinders. It will thus be seen that when the table, with the ingot resting on the rollers, was pushed by the cylinder towards the mill, the ingot, moving twice as fast, was projected over the end of the table and into the rolls. With this table was combined a manipulator which was very simple and efficient. It consisted of two hydraulic cylinders; one mounted on each side of the table, but independent of it, with the piston rods extending over it and carrying heads so shaped that by forcing them against the ingot it could be turned or moved from one pass to another. A useful feature of this manipulator was that by stopping the mill with the piece in the rolls a crooked bloom could be straightened by forcing one of the heads against it, an important advantage when ingots have been unevenly heated.

The screws of this mill were operated by a small steam engine, and the top roll was counterbalanced by hydraulic pressure.

It is a singular fact in connection with this mill, with a manipulator in successful use, that none of the numerous reversing mills built were equipped with manipulators of any kind for seven years afterwards.

While the blooming mills built up to this time had all been in connection with Bessemer works and with a view to rail manufacture, the Open Hearth process had been steadily developed since 1870, and it is to be noted that from the time when the building of Bessemer works ceased in 1875 until the phenomenal development of new undertakings following the business revival of 1879-80, the building of open hearths was about the only new work done, and the product was at first almost as exclusively devoted to plates as the Bessemer was to rails. The hard times of the last half of the decade forced the Bessemer makers to try to dispose of a part of their steel by rolling their blooms into billets on other mills; at the same time the high quality of the open hearth metal had created a considerable demand for it; but the open hearth makers labored under great disadvantages in getting their material into marketable shape, being compelled to cast small ingots and roll them on the larger bar mills. The Fritz patents had passed into the hands of an exclusive corporation, and the small size of the open hearth works, coupled with the high cost of a blooming mill, made the open hearth people hesitate before putting in so much capital to do so little work.

At last, in 1879, Shoenberger & Co. put in operation a reversing blooming mill, in connection with their open-hearth furnaces, which was the first to be built except at a Bessemer plant, and also the first to be devoted entirely to the general trade in blooms, billets and slabs.

In this mill the grooves in the rolls were of varying depth, the screws were worked by power from the shears engine through a "Hill" clutch and the tables, made of I beam frames and cast-iron rollers, were driven and reversed by the train engine direct, through belts. The rolls were driven by a pair of reversing engines which had previously been used on a gunboat, no reversing rolling mill engines having then been made in this country. This mill is of interest, as the experience gained from it was embodied in the design of the one

erected at Homestead two years later, thus having a decided bearing on the development of our modern mills, and, furthermore, because on it were made the first 4-inch billets rolled direct on a blooming mill.

The same reasons which led to the building of the Shoenberger mill caused other open hearth makers to do the same; but so firmly fixed was the superiority of the three-high mill over the reversing mill, in most minds, that the latter received but little consideration. To use three-high mills, however, the Fritz patents must be avoided, and with this object in view two mills were built, one for Naylor & Co. for billets, and one for the Springfield Iron Co. for rail blooms. The peculiarity of these mills was the table arrangement. At the back of the rolls was a table of loose rollers, lifted directly by a jack; on the front side were ordinary hooks which were raised and lowered by the motion of the back table, but through less distance. A fixed driven roller was placed over the back table in such a way that when the table was raised the ingot was forced against it and thus carried into the rolls.

Another mill should here be spoken of as illustrating the expedients to which steel works managers resorted when the Fritz patents could not be used and before mills reversing with engines were accepted as good practice in this country. It was put in at the Union Works at about the beginning of 1880 and was reversed by the surface friction of large wheels with very broad faces (twenty feet and eight feet in diameter, I think) which were forced in contact by means of a hydraulic cylinder and levers. This mill was afterwards replaced by a modern three-high mill, and should be remembered only as taking the place of the last hammers in the business, and as being the last attempt at reversing in any other way than by engines.

With the beginning of the decade 1880-1890 came great changes in the business conditions affecting the steel industry and these were quickly reflected in repairs, improvements and

additions to existing plants and the starting of new enterprises. The tremendous business expansion which began late in 1879 continued through 1880-81 and 1882, and the demand for steel works products, especially rails, was unprecedented. This demand came upon works, many of which, during the preceding five years, had been run with the least possible expenditure for repairs and were now driven to the utmost capacity. This usage of machinery quickly made necessary the replacement of several of the earlier blooming mills, while some firms added complete new plants.

In these renewals and extensions the influence of the Cambria practice of large ingots is clearly shown, all the new mills being made larger and stronger, while two mills, a three-high at Bethlehem about 1884, and a reversing mill at Cambria in 1885, following the decided tendency of the time, were made forty-eight inches in diameter. The conclusion seems to have been reached, however, that equally good results may be obtained from somewhat smaller mills and none have since been set up of over forty inches.

With this group of new mills the three-high mill reached a fixed standard which we may call the modern three-high blooming mill, the first one embodying all its characteristics, having been putdown at Chattanooga in 1878, and since this time no appreciable change has taken place. In these mills the rolls are all fixed, the tables are raised and lowered by a horizontal cylinder connected with L cranks and links, and the table rollers are driven by an independent reversing engine through gears carried by a lazy tongs.

How thoroughly efficient this kind of mill has proved itself for the making of rail blooms is shown by the fact that in all the new work intended for rail making, in the decade which we are now considering, all but two were of this description —one at Scranton, and the other at the Cambria works. In this latter case the necessity of making various sizes for other purposes than rails largely governed the choice, and it is of interest that this mill replaced the original Fritz mill.

Of the many new enterprises inaugurated during this period, the works erected at Homestead in 1881 by the Pittsburg Bessemer Steel Co. from the plans of Mr. James Hemphill claims particular attention. This plant, the beginning of the great establishment now located there, was the first Bessemer works especially built to manufacture steel for other purposes than rails; it was also the first to be put in operation after the expiration of the essential Bessemer patent, and in its construction a number of patents, supposed by many to be indispensable, had to be avoided.

In designing the blooming mill the experience gained in the "Shoenberger" mill—alluded to earlier in this paper—was largely availed of, and several features afterwards generally used in American reversing blooming mills were introduced. The mill was driven by the first American reversing engine intended for rolling mill use; the rolls were made with all the grooves of equal depth, thus permitting the adoption of straight table rollers and the making of many sizes on one pair of rolls, and the roll screws were worked by a hydraulic cylinder through a rack and multiplying gear. The tables were constructed with I beam frames and the table rollers were driven by an independent reversing engine, the ingot being handled and turned on the tables by ordinary hooks hung from above, and tongs.

This mill proved itself very efficient, and during the following years many mills of similar character were built, the building of blooming mills receiving great impetus by reason of the change of the material used in cut nails from iron to steel and by the increasing demand for Bessemer billets, which followed rapidly when once they were fairly on the market.

In these mills, about the only changes from the Homestead mill was the substitution of heavy cast iron table frames for the I beam construction, and a simplifying of the table driving gearing.

It was on one of these mills, at the Spang Steel works in

1885, that the first manipulator after the Cambria one of 1878 was tried, and after that they came slowly into use.

Another mill which should be mentioned in connection with the new enterprises of this time, is one which was put to work at Scranton for making rail blooms, in 1883. This mill, with its engine, was imported from England, and is the only complete mill ever brought from there. It was a good sample of the typical English mill of the time; very heavy and with great power. The tables consisted of loose rollers, their necks running freely on rails, and the ingots were handled on these with tongs. This table arrangement, which was never copied by American mills, was replaced some years later by a modern driven roller table. This mill seems to have had some influence in calling attention to what could be done by increasing the engine power of our mills, which was emphasized later by the work of the Sparrow's Point mill.

With the decreasing requirements for rails in this decade, and the ever-increasing demand for steel for other purposes, the three-high mill, except for replacements in rail works, received but little attention. It seemed to be accepted, as fact, that the two-high mill was best where a wide range of work was to be done. It is for this reason that a mill put down at the Otis works, at Cleveland, to combine the advantages of both systems, requires description, being the last of the modifications of the three-high mill.

In this mill the bottom roll was fixed, the top roll was counterbalanced and worked with screws in the same manner as the top roll of a two-high mill, while the middle roll was thrown up and down between passes as in a three-high plate mill; the collars being made extra wide, to support the middle roll which rested against them when working. The Fritz tables of this mill were thirty feet long, and the only ones of that type ever fitted to a mill for general bloom and billet work.

With the beginning of the present decade practice had be-

come so established that but one mill may be considered as particularly departing from it. This is the Sparrow's Point mill, which is the only thoroughly American reversing mill which has yet been intended exclusively for rail blooms, and is noticeable chiefly for the great power of its engines, which demonstrated the capacity of this form of mill when properly engined; and since the installation there has been a marked increase in the power provided for mills of its class.

The three-high blooming mill reached its highest development at about the time that the two-high mill began its career, and within ten years of its inception; and since that time their number has diminished rather than increased, partly because of a reduction in the number of rail-making establishments, in which field it has maintained its preëminence, and shows how thoroughly adapted it was to the purpose for which it was intended.

With the two-high mill it is a story of progressive development for nearly twenty years. We did not begin with this kind of mills until it had been in use abroad for many years, but we availed ourselves little of foreign experience and followed lines of our own, improving and altering our original designs.

The first table frames made of I beams were displaced by cast iron with the bearings cast on; these were followed by built up wrought-iron and cast-iron frames with separate bearings; the present table frame being a substantial cast-iron bed plate with the bearings bolted on, and in some instances water cooled.

Table rollers of cast iron with wrought axles cast in were quickly abandoned for the wrought-iron pipe roller in general use on the three-high mills; then came the steel casting with the necks cast on, and to-day the preference is divided between these and a roller made of a cast-iron body fitted with a forged axle.

The driving of the table rollers began by taking power

from the main engine, which was soon changed to the use of a separate engine driving both tables together through a countershaft; and finally the countershaft has been done away with, an engine coupled directly to the line shaft being used for each table. At the same time there has been a steady improvement in the table gearing. In the earlier mills the rollers were divided into groups driven by spurs and idlers; the number of these has been gradually reduced until each separate roller is now driven by a mitre gear, and there is not a single intermediate gear or countershaft of any kind in the best mills.

Manipulators, after a few trials, superseded the old-fashioned hooks and tongs, and since 1890 have been in general use. In this matter alone there seems still to be a difference of opinion, and some half dozen kinds have their advocates.

In the mill itself, we have finally widened the windows of the housings so that the rolls may be changed through them; and we now generally use hydraulic counterbalancing for the top roll—methods which have prevailed in other countries from the beginning, but which we reached rather by evolution than by imitation. For working the roll screws there has been but slight change since hydraulic power took the place of belts and engines, although electric motors are used on some mills requiring extraordinary lift to the top roll.

The early mills were driven by engines with gearing of three or four to one; these ratios have been steadily cut down until gearing has been abandoned, and the latest mills are connected directly to the crank shaft.

It seems as though the work of simplifying the two-high mill has about reached its limit, and, like the three-high mill of fifteen years ago, there is little room left for further improvement.

DISCUSSION OF MR. CROOKER'S PAPER.

Being called upon by the chairman, Mr. Diescher stated that he had nothing to add to the remarks of the reader on the paper, but that he felt the paper was worthy of a full

discussion, and he was confident the author of the paper was loaded and primed for any questions which might be asked him.

Mr. Julian Kennedy.—I do not know that I have anything to add to what the reader of the paper has stated. I agree fully with his general conclusions.

Col. T. P. Roberts.—I am always glad to increase my knowledge of rolling mills, and was pleased to hear the paper read by its author. In the beginning, he refers to the abandonment of the hammer process. I did not gain an exact idea from the reader whether he considered that rolling improved the quality of the metal, or whether the hammer was abandoned because it was not economical. I would like an expression of opinion upon the matter from the reader of the paper. I do not hear much about the hammer process now-a-days. I am not referring to armor plate or anything of that sort, but ordinary bar iron and steel. Was it a question of economy which led to the abandonment of the hammer, or is the product of the roll superior?

Mr. Ralph Crooker, Jr.—A number of years ago, I was interested in some experiments to ascertain which process produced the best metal, and I think the result proved very conclusively that the rolling process was superior. All the highest class iron in the world to-day is made by rolling.

C. B. Albree.—I think there is considerable good metal produced to-day by the hammer process. Is not all tool-steel so produced?

Mr. Crooker, Jr.—The hammer in making tool steel is largely used in shaping the metal; it has nothing to do with the quality of the steel.

Col. Roberts.—It seems to me Mr. Crooker, that the general impression existing in the public mind to-day, is that hammered iron is superior to rolled iron, and that the hammering adds to its strength, to its density, and to its value. Of course the reader of the paper knows very much more about this matter than I do, but I think I am giving expres-

sion to the general opinion on this subject. There is one thing certainly true, and that is in the hammering process the metal is constantly under the eye of a skilled mechanic. If he comes to a flaw, it is cut out and the bar made shorter. Now, in the rolling process, there is not this personal equation, if we may so call it, that is, the rolls are incapable of passing judgment, the machine does everything and there is very little chance for close scrutiny of the metal by a skilled mechanic.

CHAIRMAN.—I believe that all car axles are made under the hammer, are they not?

MR. KENNEDY.—I think when the mechanical difficulties, which lie in the way of rolling car axles are overcome, that as good axles will be made by the rolling process as by the hammer. I suppose, at the present time, about 75% of the axles are made by the hammer process.

MR. W. E. KOCH.—I notice that a mill in Belgium produces axles under hydraulic pressure.

CHAIRMAN.—Is that a single or repeated process?

MR. KOCH.—A repeated process.

CHAIRMAN.—Is the pressure brought on to the axle repeatedly, or just enough to shape it?

MR. KOCH.—I think there are four processes, two on one end and two on the other. I have seen the process described in a French metallurgical journal.

I was going to speak about the hammer in the old days. Starting in previous to the 70's, ingots were small, 9″ to 10″ and 12″. With these ingots, there was no trouble with the hammer. But the trade demanded larger ingots for heavier rails, as large as 15″ and over, and this made slow work at the hammer.

In those days they always required a certain proportion of Swedish pig iron in the steel. It was often specified that there must be one-third or one-half Swedish pig iron in the converter. When that steel was brought down to the hammer, if it cracked it was rejected and went as a second.

And then again, the hammer men made so much money that after every pay Saturday there was a shut-down on Monday until the men could be gathered up again. This state of affairs led to the blooming mill quite rapidly.

The first really successful blooming mill which I remember was one built by Tannett & Walker, of Leeds, about 1872. I do not remember ever seeing a better piece of machinery. The details were carefully worked out and everything was as perfect as good mathematics could make it. It ran for years with no trouble or expense of any kind.

Mr. Lewis.—In regard to the question of making car axles, I will say that there is a mill at Beaver Falls which is attempting to produce a railroad axle by rolling between a large roll and a fixed outside die covering about one-half the circumference. It is said to be producing a good article.

Mr. Crooker, Jr.—The majority of hammered axles are merely axles that are rolled within one-eighth or one-quarter of the size of the largest part, and the final shaping is done by the hammer.

Chairman.—Can you explain how the word "bloom" came to be applied to the metal?

Mr. Crooker, Jr.—No, sir, I cannot; that matter has been discussed many times. It is probably a wrong use of the word, but it has come to be very common.

Mr. Kennedy.—I think the question of labor had more to do with the rapid advance in mill machinery than anything else. The men made large wages, and could not be depended upon for steady work, and machinery was invented to take the place of unreliable mechanics. Trades unions, and all that sort of thing, were started, until a mill man never knew whom he could depend upon to run his mill.

Mr. Flannagan.—I would be pleased to have the reader of the paper explain the relative advantages of the two-high and the three-high mills, and the reason why one is especially adapted to railroad work and the other to other classes of work.

Mr. Crooker, Jr.—That question, if entered into fully, would require a long explanation. Briefly it has been found that in the three-high mill the rolls had best be fixed, and this limits the number of passes which can be made on one set of rolls and consequently the amount of reduction that can be made on an ingot. As the sizes of the rail blooms are mostly between the dimensions of seven and eight and one-half inches, the amount of reduction required brings them within the limits of the three-high mill's work, and also brings the length of the piece within the length which can readily be handled on the lifting tables. The accurate size of work done on fixed rolls together with the large tonnage and small number of men required to handle it, makes the three-high mill peculiarly adapted to feed a rail mill, or for any similar work where only large blooms are required.

The two-high mill can handle a very much greater range of sizes because the top roll is movable and can come down to much smaller sizes, as the tables, which are fixed, are easily made of any desired length, almost always exceeding one hundred feet, which is much greater than it is reasonable to attempt with a lifting table.

Again, in using a movable roll, which precludes the use of strong fixed guides, the two-high mill may be instantly stopped if a piece turns down, or enters between the collars, thus avoiding accidents ; while with a movable roll in the three-high mill, which is necessary in order to make a variety of sizes, a disaster would be very likely, as the mill could not be stopped. For these reasons the two-high, reversing mill seems best for general purposes.

A complete consideration of this subject would quite exceed the limits of the paper itself.

Mr. W. A. Cornelius.—A few words of actual experience in the way of discussion may be of interest in connection with Mr. Crooker's most valuable paper.

At the works with which I am connected, we have mills

of the two types, viz.: three-high and two-high, which are so nearly of the same size that a very good comparison can be made between them. The three-high is in my own department and the one with which I am, of course, the most familiar.

We often hear the broad assertion made "three-high is the better mill for all purposes," and again by another "two-high," but such broad assertions cannot be made; for, as Mr. Crooker says, three-high is better for one purpose, and two-high for another. Now, from our experience with the two mills referred to above, on large size blooms, say from 7″ x 8″ up, the three-high mill will roll more tonnage than our two-high, but for sizes below this the two-high reversing mill will turn out far more tonnage.

The reason for this is obvious. With the three-high mill there must be some kind of lifting tables to raise the piece from the bottom to the top pass. These, of necessity, must be comparatively short, some 20 feet. Now, provided the piece in rolling does not roll out so long that the end overhangs the end of the table and sags down, it can be manipulated, that is, turned over and pushed from pass to pass, as fast, if not faster, than on a stationary table; but as soon as the piece overhangs the table to such an extent that it sags down and becomes curved, then trouble begins and time is lost in the effort to turn the piece over and get it in line with pass.

I have seen a piece turned over and gotten in line with the pass three times, and each time, as the table lowered, the overhanging end would strike and roll the piece back again into the original position, making it necessary finally to run the end up on the table again and straighten it with the manipulator—bad practice, for it strains both manipulator and side guards, but a practice which is absolutely necessary with the rolling of smaller sections on a three-high mill.

All this takes time and reduces tonnage. Therefore, you can clearly see a three-high mill is not adapted to rolling small sizes which run out into long lengths; while on a two-high

there is no lifting table, the piece lies level, and little or no trouble is experienced in turning pieces over, either 60, 80 or over 100 feet long.

Mr. Bole.—Can you throw a little light on the mathematical calculation of the strain thrown on the housing?

Mr. Crooker, Jr.—There is great difficulty in arriving at any exact mathematical estimate of this matter. The housings are built up as they break down; it is a matter of building up, and the strength of the housing is estimated almost entirely upon past experience.

Chairman.—Do I understand that the matter of housing, that is, the strength of the housing, is a matter of experience and practice, and not subject to mathematical calculation?

Mr. Crooker, Jr.—It is a matter of practice and experience almost entirely.

Mr. Hirsh.—What causes the breaking of the rolls?

Mr. Crooker, Jr.—Plate rolls may be broken by carelessness. Blooming mill rolls rarely break unless they are used until they are full of fire cracks.

Mr. Kennedy.—The mills at Vandergrift have a two-high reversing blooming mill taking over 16″ by 18″ ingots, to 7-1\2″ by 4″. The finishing mills are composed of two groups, each containing three pairs of rolls, the operation requiring about three minutes. Probably it will soon be possible to roll 280 foot bars.

Chairman.—How far is it from the first set of rolls to the farthest?

Mr. Kennedy.—It is about eighty feet from the first to the second, and two hundred and fifty through to the shears. The rolls are about sixteen inches in diameter, and are very short, about fourteen inches long, making them quite strong.

Mr. Bole.—Col. Roberts' question as to the relative advantages of hammering and rolling might be carried a little further. Mention has been made of tool steel. I do not know

any person, myself, who uses rolls for producing tool steel. I presume one reason is that the working it down to a black heat has a great deal to do with the ultimate quality of the steel. This might explain the almost universal practice of using the hammer to produce tool steel bars.

Mr. Croker, Jr.—That is simply a condensing of the surface of the steel. It produces practically the same effect as cold rolling does. It condenses the surface, but it does not change the quality of the tool steel itself.

Chairman.—The advantages are only skin deep then?

A Member.—It is especially important that metal for railroad work should be so prepared as to render danger from fracture least likely. The fiber of the outside must not be destroyed, as in an axle, for instance. For hardening the surface of metals, hammering has generally, heretofore, been considered a preferable method.

Mr. Koch.—There is lots of tool steel which never saw a hammer, but is just cold rolled.

Mr. Flannagan.—There seems to be considerable mystery with regard to the turning of rolls. I would like to ask some of the gentlemen how long it takes to acquire this knowledge.

Mr. Kennedy.—It takes a good long time and a good deal of experience. It takes a man with remarkably good judgment to understand roll turning for all sorts of sections. It is much more complicated than it looks, and there can be no method of instruction given which will take the place of experience, training, and judgment.

Mr. Koch.—There are certainly lots of poor roll turners around mills to-day. A man has got to start as an apprentice to the best man he can find, and he must stay with him for a long time, and be taught by long experience before he can be trusted to perform the work himself. It takes long years of watching and study.

Mr. Crooker, Jr.—There never has been a book written on this subject which amounts to anything. I have examined two or three, and the most important things were left out.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the rooms of the Society's house, No. 410 Penn Ave., Pittsburgh, Pa., Tuesday evening, September 21. The meeting was called to order at 8:40 by the vice-president, Mr. G. S. Davison. About fifty members and visitors were present, among the latter being a number of prominent iron men of this city. The minutes of the preceding meeting were read and approved. The report of the Board of Directors was called for, and Mr. G. S. Davison made the following informal report:

MR. G. S. DAVISON.—I have no formal report to make on behalf of the Board of Directors, but it may be in order to mention a very important matter that was discussed by the Board a few evenings ago. The Board went over, very carefully, the list of members who are back in their dues. They found that about one-half the members of this society had not paid this year's dues. These have been due since the first of last January. About one-third of the members had not paid this year's dues nor last year's either, and are therefore two years back, and some members are in arrears still more. The Board found that there was due the Society some $2,000.

I mention this matter to-night because I feel it is of great importance to the society, and because there are some members present to-night who are in arrears. An opportunity will be given them to pay up. Those who are not in a position to pay this evening need not be surprised to be called upon by the treasurer in the near future. The Board of Directors feel that this matter of back dues is largely a matter of over-sight,

and that when attention is called to it, a prompt settlement will be made. It will be a very great benefit to the society to have this money in the hands of the treasurer.

The next order of business was the election of new members. Mr. L. J. Daft was voted upon, the chairman appointing Messrs. Marden and Fohl as tellers. After counting the votes, the tellers reported that the candidate had received thirty-three votes, and the chairman declared him elected to membership in the Engineers' Society of Western Pennsylvania.

The question of "International Metric System of Weights and Measures" was voted laid on the table.

For the Committe on Power, Mr. Fischer reported that the answers to the list of questions sent out some time ago had not commenced to come in very rapidly, owing, undoubtedly, to the warm weather. He suggested that a proper notice be inserted in the next regular notices for a meeting of the society, stating that the committee on Power wishes the co-operation of the members in securing data as to the actual cost of power. The answers to inquiries received were hardly sufficient to warrant the committee in bringing them before the society that evening.

For the Committee on Roads, Mr. Diescher stated that they had a report ready for presentation to the Society, but that is was a very lengthy one and would consume time which properly should be devoted to the reading and discussion of the regular paper of the evening. The preparation of the report cost a great deal of time and labor, and in the opinion of the committee was deserving of an evening for reading and full discussion.

It was then voted that as there was no paper assigned for November, the report be made then.

Mr. Engstrom reported for the Reception Committee, that they had been unable to secure a boat for the proposed Society excursion, which had consequently been abandoned.

On behalf of the committee, the secretary read a memorial on the death of Mr. Fred Heron, which was voted spread on the minutes of the Society.

Chairman.—I have before me an invitation to the members of this society, presented by Mr. C. W. Townsend, on behalf of Messrs. Westinghouse, Church, Kerr & Co., inviting the society to visit the Exposition this evening. I suppose if we adjourn in sufficient time, many of the members will be pleased to accept this invitation.

Upon a motion, a vote of thanks was extended to Mr. C. W. Townsend, and to Messrs. Westinghouse, Church, Kerr & Co., for the invitation.

Mr. Ralph Crocker, Jr., here read the paper of the evening, entitled: "The Development of the American Blooming Mill." Pages 325 to 339 of Proceedings.

After discussing this paper (pages 339 to 346), the meeting adjourned.

Reginald A. Fessenden,
Secretary.

MEETING OF THE CHEMICAL SECTION.

PITTSBURG, PA., Sept. 23, 1897.

The regular monthly meeting of the Chemical Section was held in the Lecture Room of the Engineers' Society, 410 Penn Ave., Sept. 23, 1897.

Chairman, W. E. Garrigues.

Attendance, 15.

No business was transacted. Mr. O. I. Affelder read the paper for the evening on Formaldehyde. The paper was discussed by Messrs. Garrigues, Phillips, Handy, Wilkins and others. The Section adjourned at 9.45.

A. G. McKENNA,
Secy. C. S.

FORMALDEHYDE.

BY O. I. AFFELDER.

Before the discovery of the antiseptic and disinfectant properties of formaldehyde by Berlois and Trillat, in 1890, very little was known of this compound, other than the fact that it existed. Some few German and French chemists had published results of experiments with formaldehyde, but the interest of the scientific world in general was not aroused until the discovery of its wonderful germicidal properties. Since then, very few issues of chemical or medical journals have appeared without mention of some fact or facts emphasizing its superiority over practically all other existing disinfectants and antiseptics.

Assuming that the people interested in this compound have a more than limited knowledge of this branch of the subject, I have made the object of this paper an elucidation of other features.

I have subdivided the subject into preparation, reactions and determination. Under "preparation," I will describe and

give results of experiments with a method for the preparation of formaldehyde in the laboratory. Under this heading I will also treat briefly the subject of lamps or generators for the production of gaseous formaldehyde for disinfectant purposes. Under "reactions," but a few of the more interesting of the many reactions will be given. Under "determination," several of the most reliable methods for determining formaldehyde quantitatively will be described.

PREPARATION.

Formaldehyde was first prepared by Hofmann, in 1867, by passing the vapor of wood alcohol over ignited platinum. For this purpose he used a three-necked flask of about two liters capacity and filled about five centimeters high with warm wood alcohol. One neck was provided with a cork, and a tube which passed to the surface of the liquid. The other necks were provided with glass tubes; the middle one carried a platinum spiral which was brought nearly to the surface of the alcohol. The third opening was connected with the upper end of a condenser, the lower end of which was connected with a two-necked receiver; this receiver was connected with a series of wash bottles, the last of which was conneeted with a suction pump by which a rapid current of air was drawn through the whole apparatus. The platinum spiral was heated and lowered into the bottle when the flameless combustion of the alcohol manifested itself by the evolution of a gas powerfully affecting the nose and eyes. This mode of generating formaldehyde is very dangerous, as a sharp explosion sometimes takes place at the beginning of the experiment.

All the methods of preparing formaldehyde, with very few exceptions, are based on Hofmann's method, as described. The following is a description of a method for the preparation of formaldehyde in the laboratory, as recommended by Bender and Erdmann (Chem. Preparaten Künde., II., p. 123); it is a modification of the method described by Tollens (Ber. der deutsch, Chem. Gesell, '82, 1629).

Two hundred cubic centimeters of methyl alcohol are placed in a half litre flask G, heated on a water bath to 40°C., and by means of a suction pump, air is aspirated through it. The air is first passed through a tube I containing $Ca\,Cl_2$ and then through a wash bottle containing concentrated $H_2\,SO_4$. It is then allowed to bubble through the methyl alcohol by a tube reaching just below the level. The air laden with alcohol vapors is now passed through a slightly ascending glass tube E about 30 cm. long, lined throughout with sheet mica, and in which is a roll of coarse copper gauze about 5 cm. long. The tube containing the copper gauze is connected with the receiver C, by means of a U-tube D. On the other side of the receiver are two wash bottles, A and B, each being partly filled with water ; A is connected with the suction pump.

The first experiments were tried with the apparatus just as described; it seemed to work satisfactorily except that no aldehyde was collected in the receiver C. At about 400°C., the first tube broke from the alcohol which condensed in the upper end of the tube E, running back. This tube had hardly been replaced when the alcohol in the flask G exploded from the vapors in the tube E flashing back. In order to prevent any further accidents from this source, there was inserted between the tube E and the flash G, a safety tube F, consisting of a piece of half inch glass tubing six inches long, with a roll of copper gauze two inches long at the center. 100 cc. water were placed in the receiver C in order that the formaldehyde collecting there could be determined.

Several experiments were tried with the apparatus in this shape. At 132° C., a heavy precipitate was formed by boiling 5 cc of the solution from C with a few drops of an ammonical silver nitrate solution. Although the temperature was carried up as high as 800°, not enough aldehyde was collected in the bottle C to be determined by a normal ammonia solution, but it was noticed that the alcohol which condensed in the U-tube D, smelled very

strongly of the aldehyde. After this had been noted, the product was collected in the U-tube, and a quantity of aldehyde enough to be determined by a normal ammonia solution was obtained by letting the apparatus run for thirty minutes at a temperature as low as 183°.

The apparatus was now working as satisfactorily as could be hoped for except that every time the tube E was allowed to cool it broke. This was so annoying that it was decided to try an iron pipe in place of the glass tube. For this purpose a piece of one-half inch gas pipe twenty inches long was used, and by means of bushings and reducers, a piece of one-eighth inch pipe was screwed to each end of the one-half inch pipe in order that the ends would not get too hot for the rubber connections. In this shape the apparatus was complete in every respect and gave perfect satisfaction.

The following are results of experiments carried out for the purpose of finding out the most enonomical quantity of air to aspirate through the apparatus ; these results represent but one quarter of the yield, as the distillate collected in the U-tube D was diluted to 20 cc. and 5 cc. taken for the determination. The formaldehyde was determined by a normal ammonia solution ; the details of the method will be described later.

TEMP. IRON PIPE.	TEMP. ALCOHOL.	CC. NH_4OH.	WT. NH_3.	WT. CH_2O.	RATE AIR CU. FT. PER HR.
250°	55°	0.2	0.0034	1.0100	0.300
275°	54°	0.7	0.0119	0.0313	0.384
260°	55°	1.5	0.0225	0.0675	0.600
265°	55°	2.4	0.0408	0.1080	0.666
260°	55°	1.4	0.0238	0.0640	0.936
260°	55°	1.0	0.0170	0.0450	1.076

From these results it will be observed that by keeping the temperature of the iron pipe and the temperature of the alcohol practically constant, and by gradually increasing the rate of the air current, the yield first increases and is greatest where the rate of the air current is about 0.7 cu. ft. per hour; when the rate is further increased the yield of formaldehyde is lessened and steadily decreases.

The following are results of experiments tried with a view to finding the effect of changing the temperature of the iron pipe:

TEMP. IRON PIPE.	TEMP. ALCOHOL.	RATE AIR CU. FT. PER HR.	CC. NH_4 OH.	WT NH_3.	WT. CH_2 O.
200°	56°	0.620	0.4	0.0068	0.0180
225°	56°	0.600	0.8	0.0136	0.0360
260°	55°	0.600	0.7	0.0119	0.0313
340°-360°	55°	0.630	0.6	0.0102	0.0270
404°-450°	57°	0.600	0.5	0.0085	0.0225
530°-593°	56°	0.620	0.5	0.0085	0.0225

The above results are averages of three such sets of experiments. In making these experiments some difficulty was experienced in regulating the conditions. Taking this into account, it was observed that it takes a temperature of about 250° C. for the production of the formaldehyde in any appreciable quantity; that at about 350° the yield is greatest, and that raising the temperature over this mark causes no marked effect on the yield.

LAMPS.

For the application of formaldehyde as a disinfectant, a ten to forty per cent. solution is generally used, from which the gas is driven by evaporation, or by heating the solution in

some suitable vessel. This method, while it fulfills the requirements, would be expensive on a large scale.

Several lamps or generators for the production and simultaneous setting free of the gas, have been put on the market. They are nearly all constructed so as to cause the incomplete combustion of methyl alcohol, by burning the alcohol in a confined space, and by limiting the supply of air. The main objection to lamps of this sort is that most of the alcohol is burned to CO_2 and water, and very little is turned into formaldehyde.

Figure 1 represents a very simple form of a lamp for the production of formaldehyde. It consists of a bottle A, containing methyl alcohol, and having a cork with a tube through the middle carrying the wick B. By lighting the wick, and then placing over this an eight-inch piece of one.inch glass or metal tubing D, with some copper gauze C, at the lower end, formaldehyde is generated at once. The efficiency of this lamp was tested by placing a large funnel over the chimney, and collecting the formaldehyde by means of A, B and C of the Tollen's apparatus. The quantity of the gas collected was determined, and it was found that in a given time, there was produced by this simple apparatus, about eight times as much of the aldehyde as the Tollen's apparatus .produced under the most favorable conditions.

Figure 2 represents the chimney of the Moffatt Formaldehyde Generator. It resembles very much the chimney of a Bunsen burner. It is nine and a half inches high, one and a half inches at the bottom and one inch in the diameter of the upper part. At points four and one-half and six and three-fourth inches from the bottom of the chimney, and on opposite sides of the chimney, are two semi-circular plates, evidently put there for the purpose of limiting the supply of air. The rest of the generator is essentially an alcohol lamp, burning methyl alcohol by means of a half-inch wick. The formaldehyde is generated by lighting the wick and placing the chimney over it.

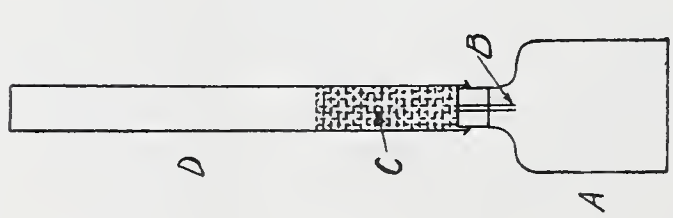


Fig 1

Fig 2

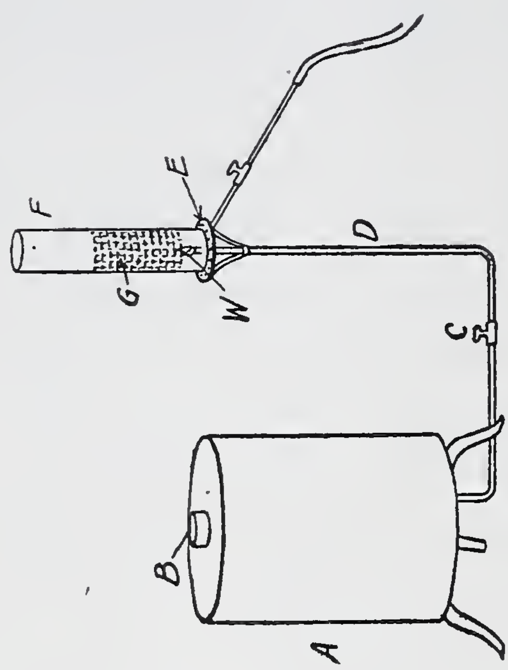
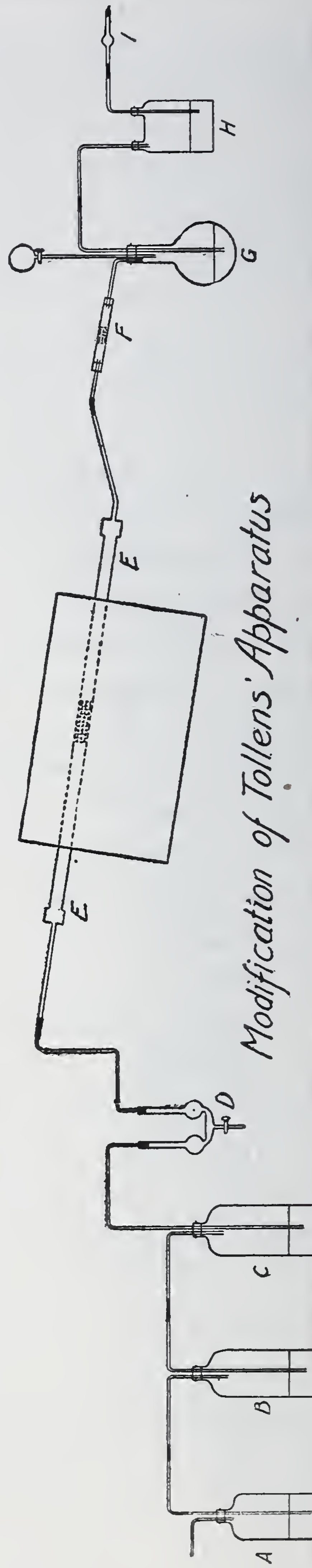


Fig 3



Modification of Tollens' Apparatus

In the lamp just described, alcohol was burned and a considerable quantity wasted in this manner. In order to overcome this objection a plan was conceived whereby no alcohol was burned and by which the heat necessary for the reaction and for the evaporation of the alcohol was furnished by burning gas, a less expensive fuel than the alcohol.

Figure 3 shows a lamp which was constructed on this plan. A is a tank which is filled with wood alcohol by means of the opening at B. D is a half-inch pipe carrying the wick W. E is a circular burner, F is a metal chimney fitting in the burner in such a manner that the flame burns against the outside; at the bottom of the chimney is a roll of metal gauze G. Formaldehyde is generated in large quantities by lighting the gas and turning on the stop-cock at C. To collect the gas in order to determine the efficiency of this apparatus, a piece of one-inch iron pipe was slipped over the chimney to within two inches of the bottom. To the upper end of this pipe a piece of eighth-inch pipe was screwed at right angles to it by means of bushings, reducers and an elbow. To this were attached two wash-bottles, each containing 100 cc. water; the second bottle was connected with a suction pump. The formaldehyde which was collected was determined and it was found that in fifteen minutes, there was produced eight times as much as the most the Tollens apparatus produced in thirty minutes. This apparatus was left burning in a room of 4,000 cubic feet, and in twenty minutes it was impossible for any person to remain in the room; in this time about 12 cc. of the alcohol had been used. The Tollens apparatus produced in thirty minutes 0.0775 gm. of formaldehyde; the apparatus represented by figure 1 produced 0.62 gm., while the apparatus represented by figure 3 produced 1.24 gm.

REACTIONS.

Formaldehyde is the first of the series of fatty aldehydes, but although it has the same general symbol, R-CHO, many substances which react with acetic and most of the higher alde-

hydes, have an entirely different effect, and in most cases no effect whatever, when brought together with formaldehyde.

The following are some reactions of formaldehyde :

1. One of the most delicate tests for formaldehyde is an ammoniacal solution of silver nitrate, containing some caustic soda. Tollens (Zeit. für. Analyt. Ch., 1883, 261) recommends a mixture of two solutions as a reagent for formaldehyde, the one containing three grams $AgNO_3$ in thirty grams of a concentrated ammonia solution, and the other three grains caustic soda in thirty cc. water. This mixture will keep indefinitely, but as there is a possibility of fulminate of silver being formed, it has been recommended to keep the two solutions separately. Lee (Zeit. für. Analyt. Ch., 1896, 589) suggests that the reaction, very possibly, takes place in two stages. First, the aldehyde and the silver nitrate react to produce a partial reduction, according to the equation,

$$Ag_2O+HCHO=Ag_2+HCOOH\,;$$

and secondly, by the complete oxidation of the formaldehyde, the silver is precipitated as a fine powder,

$$Ag_2O+HCOOH=Ag_2+H_2O+CO_2.$$

The delicacy of this reaction was tried, and it was found that a heavy precipitate was produced by warming one cc. of a solution of formaldehyde containing one part in four thousand with a few cc. of a one per cent. $AgNO_3$ solution.

2. The compound the delicacy of whose reaction with formaldehyde ranks next to silver nitrate, is phenyl hydrazine (Ber. der Deutsch. Ch. Gesell., 1885, 330). This is a characteristic reaction of the aldehydes.

Formaldehyde hydrazone is formed according to the reaction,

$$H.\ CHO+H_2: N.\ NHC_6H_5=H_2O+H.\ CH.\ N.\ NHC_6\,H_5.$$

By heating one cc. of a solution of formaldehyde containing one part in four thousand, with one drop of phenyl hydrazine, a slight yellowish-white precipitate was formed, while with a solution of formaldehyde containing one part in four hundred, a very heavy precipitate was formed.

3. Gold chloride is slightly reduced by a solution of formaldehyde containing one part in two thousand, while with a solution containing one part in four hundred there is a very decided reaction.

4. Hydrogen sulphide does not react with formaldehyde when the gas is merely passed through its solution, but the presence of strong acid or of some dehydrating agent is requisite for the reaction to take place. Baumann and Fromm (Ber. der Deutsch. Ch. Gesell., 1889, 2600) showed that when acetic aldehyde and benzaldehyde are treated with hydrogen sulphide in presence of hydrochloric acid, two isomeric trithio aldehydes are formed. The same reaction was tried by Baumann with formaldehyde (Ber. der Deutsch. Ch. Gesell., 1890, 60), but in all cases only the trithio formaldehyde $C_3H_6S_3$ was produced. This compound can be formed in many other ways, but as no isomeric compound has been obtained, there can be no doubt that the peculiar isomerism occurring in the higher members of this class does not extend to the lowest member.

5. By the action of chlorine on formaldehyde at a gentle heat, HCl and CO are produced (Brochet, Ber. der Deutsch. Ch. Gesell., 1896, 88 R). By the aid of sunlight even in the cold, besides HCl and CO, carbon oxychloride is formed. Bromine reacts the same as chlorine, giving analogous compounds.

6. By the action of resorcin on formaldehyde a very interesting condensation takes place, with the splitting off of one molecule of water (Caro, Ber. der Deutsch. Ch. Gesell., 1892, 947). The resorcin in a fine powder is treated with a forty per cent. formaldehyde solution and some hydrochloric acid; on standing several hours, a white powder separates which is insoluble in water, soluble in alcohol, ether and alkalies, and decomposes at about 250° C. The following equation expresses the change:

$$H.\ CHO+2C_6H_4(OH)_2=C_6H_3(OH)_2—CH_2—C_6H_3(OH)_2+H_2O.$$

7. If an excess of formaldehyde solution is added to a solution of hydroxylamine hydrochloride, all the hydrochloric acid of the salt is set free (Cambier, Zeit. für Analyt. Ch., 1895, 623). This can be shown by titrating with standard alkali solution, using methyl orange as the indicator. This reaction is made the basis of a quantitative determination of formaldehyde (Ber. der Deutsch. Ch. Gesell., 1895, 233). The following reaction takes place:

$$NH_2OH.\ HCl + HCOH = CH_2 = N—OH + HCl + H_2O.$$

8. Formaldehyde reacts with aniline to give the condensation product $C_6\ H_5—N=CH_2$ with the setting free of one molecule of water. In the presence of aniline hydrochloride, one more molecule of aniline takes part in the reaction to produce diamidodiphenyl methane.

$$2C_6H_5NH_2 + CH_2\ O = \begin{matrix} C_6H_4—NH_2 \\ C_6H_4—NH_2 \end{matrix} = CH_2 + H_2O$$

9. Formaldehyde treated according to Windisch (Zeit. für Analyt. Ch., 1888, 514) was found not to give the reaction with metaphenylene diamine, used for the detection of certain of the higher aldehydes.

10. Béla von Bittó (Zeit. für Analyt. Ch., 1893, 351) gives a table showing the reactions of meta dinitro benzene on various aldehydes, but formaldehyde is not included in the list. The aldehyde is dissolved in alcohol; a few drops of an alcoholic solution of M-$C_6H_4(NO_2)_2$ and a little potash solution are added. This was tried with a few drops of a ten per cent. formaldehyde solution, and a bright yellow color appeared on standing.

11.—Formaldehyde, like the higher aldehydes, restores the red color to a solution of fuchsine which has been bleached by sulphurous acid.

12.—Permanganate of potash is reduced by formaldehyde, producing carbon dioxide and water (Lee, Zeit. für Analyt. Ch., 1896, 589).

13.—By treating formaldehyde with lime water, it is polymerized into formose, a mixture of sugars (Bloxam's Chemistry, 714).

14.—By the action of chlorate of potash on formaldehyde, the latter is oxidized into formic acid (Grützner, Zeit. für Analyt. Ch., 1897, 165).

QUANTITATIVE DETERMINATION.

The following are a few of the methods for the quantitative determination of formaldehyde, which were thought to be the most reliable:

1.—Grützner (Zeit. für Analyt. Ch., 1897, 165) describes the following method:

In a closed flask 5 cc. of the formaldehyde solution with one gram $KClO_3$, a little nitric acid and 50 cc. of a tenth normal silver nitrate solution are heated on a water bath for half an hour. When cool the excess of silver nitrate is titrated with a tenth normal solution of ammonium cyanide, using a concentrated solution of ferric alum as the indicator. The reaction takes place in two stages:

(a) $KClO_3 + HCHO = KCl + HCOOH$

(b) $KCl + AgNO_3 = KNO_3 + AgCl.$

2.—Legler (Ber. der Deutsch, Ch. Gesell., 1883, 1333) recommends a normal ammonia solution for the quantitative determination of formaldehyde. He cites trials of the method under varying conditions of temperature and dilution, and shows the results to be very satisfactory. 5 cc. of the aldehyde solution to be tested are placed in a bottle and allowed to stand tightly corked for five minutes with an excess of the ammonia solution. The excess of ammonia is titrated with a normal hydrochloric acid solution, using litmus.

$$6HCOH + 4\ NH_3 = (CH_3)_6N_4 + 6H_2O.$$

3. The reaction of aniline with formaldehyde is made use of for a quantitative determination of the aldehyde. A solution of three grams of aniline in one liter of water is standard-

ized by titrating with a tenth normal hydrochloric acid solution, using Congo red as the indicator. For the determination one cc. of the formaldehyde solution and 40 cc. of the aniline solution are placed in a half-liter flask and diluted to 500 cc. with water. This is filtered through a dry filter into a dry flask and the excess of aniline in 50 cc. is titrated with hydrochloric acid solution.

$$HCHO+C_6H_5NH_2=C_2H_2N\ C_6H_5+H_2O.$$

MEMORIAL ON THE DEATH OF MR. FRED HERON.

The subject of this sketch, Mr. Fred Heron, a member of the Engineers' Society of Western Pennsylvania, died April 5, 1897, of acute kidney trouble.

He was born at Bedford, Yorkshire, England, June 26, 1856. He was engaged in his native country in the machinery business, and was a thoroughly trained machinist and a competent draughtsman.

Coming to the United States in 1880, he first secured employment at the works of Mackintosh, Hemphill & Co., Pittsburg, Pa., as a machinist. He showed such active ability and adaptability to his work, that he was transferred to the drawing office, where he fully sustained his former reputation for push and good work. He was afterward engaged as master mechanic by the Pittsburg Bessemer Steel Co., whose works were located at Homestead, remaining there for some time afterward. The next position held by him was the superintendency of the steel department of the Phœnix Iron Company, at Phœnixville, Pa., from which position he was in a short time promoted to the general managership of the entire works. He resigned this position in 1896 to enter the employment of the Universal Construction Co., at Chicago, Ill.

He was a thoroughly tireless worker of highly developed mechanical ability, exceedingly practical, and keen to perceive economic advantages or disadvantages in manufacturing. He was very ingenious, and, while a pusher of men, was singularly considerate of them.

He was a man whom to know was to esteem, being of such a kindly, cheerful, and genial disposition as to draw friends to him from those with whom he came in contact, and to hold them, being generous to a fault.

Careful in arriving at a conclusion, he was prompt to carry out any plans which he had determined upon; and gave his best faculties to any interests with which he was identified.

We, his friends, can only add our tribute of respect and affectionate regard to his memory, which it was impossible not to feel for him while living by those who knew him best.

P. T. Berg, } Com.
E. F. Wood, }

Munhall, Pa., June 29, 1897.

FIRST REPORT OF COMMITTEE ON ROADS.

Following is a list of specimens of stone pavements imported and exhibited by Mr. Arthur Kirk, at Pittsburg Exposition.

Exhibit No. 1. One square yard of granite pavement, furnished by Mr. James Daiz, engineer in chief, Clyde Navigation Co., at Glasgow, Scotland.

Welsh granite—Blocks are $3\frac{1}{2}$ inches wide, $8\frac{1}{2}$ inches long and $5\frac{1}{2}$ inches deep. Forty-one blocks in one square yard.

Foundation consists of 8 inches concrete of one part Portland cement to 6 parts of sand.

On top of this concrete is a two inch thick layer of sand and on this rest the blocks.

The joints are from $\frac{1}{4}$ inch to $\frac{5}{16}$ inch wide, and are filled out with pitch.

Exhibit No. 2. Furnished by Mr. James Morgan, chief engineer of the city of Liverpool, England.

"A." One square yard of pavement, blocks $3\frac{1}{2}$ x $3\frac{1}{2}$ x 6 inches deep. Foundation consists of six inches of concrete and $\frac{1}{2}$ inch of sand bedding over concrete. The joints are $\frac{1}{4}$ inch thick and filled with pitch.

"B." From same exhibitor another square yard of pavement, blocks 4 inches thick, 8 inches long and 6 inches deep, joints $\frac{5}{16}$ thick. Foundation as before. Concrete consists of 1 Portland cement, 6 sea beach gravel and eight broken limestone.

Exhibit No. 3. From the city of Hamburg, Germany. One square meter of pavement, blocks $5\frac{1}{4}$ x $9\frac{1}{4}$ x $3\frac{3}{4}$ inches deep, bedded directly in concrete and cement mortar without the usual sand layer between concrete and stones. Joints not over $\frac{1}{4}$ inch wide and filled with pitch. The area one square meter contains seven rows of blocks with $4\frac{1}{2}$ blocks in each.

Exhibit No. 4. Consists of several boxes of granite paving blocks from Halmstad, Sweden, all loose however, but

they are exceptionally well trimmed. The blocks are respectively $5\frac{1}{2}$ x $9\frac{1}{2}$ x 9 inches deep. Also, in same square yard, 5 x 8 x 9 inches deep.

Another box, 5 x 7 inches to 5 x 12x 6 inches deep.
" " 6 x 10 x 4 inches deep.
and 6 x 6 x 4 " "

Exhibit No. 5. From the "Welsh Granite Co."

One square yard of blocks, 4 x $5\frac{1}{2}$ x 4 inches deep.
" " " " $4\frac{1}{2}$ x $4\frac{1}{2}$ x 4 " "
" " " " 4 x 7 x 6 " "
" " " " $3\frac{1}{2}$ x 8 x 6 " "

of reddish granite of extra heavy weight.

All of these foreign blocks are very neatly dressed and uniform in dimensions and, therefore, they may be set much closer together than ruder stone variable in dimensions. They are so refined in handiwork as to be tapered toward the base to conform to the curved (crowned) surface of the roadway, while closely joined the whole depth.

The workmanship in shaping these imported blocks indicates great skill and exactness, for they are trimmed to uniform dimensions, have square corners, straight edges and are properly tapered toward the bottom. Owing to this exactness in workmanship, the joints between adjacent blocks, from either Liverpool, Hamburg or Sweden, are not over $\frac{5}{16}$ inches wide. This is a matter of great importance in several respects and becomes more apparent by comparison with the "Standard" block pavements on our own streets. To begin with, our blocks are not of uniform thickness, nor are they selected with respect to thickness, but they are laid promiscuously, and on this account the joints too are of various widths ranging from $\frac{1}{4}$ inch to $1\frac{1}{2}$ inches and some times beyond this. But the variation in thickness of the blocks is not the only cause of so excessively wide joints, for the very irregular manner, too, in which these blocks are trimmed is accountable for a large share of that evil. It is an ordinary occurrence that a block is

thicker, or longer, at half of its depth than across its top. In such instances the width of the joint is determined by the greatest projections from opposite surfaces of adjacent blocks. The unavoidable consequences of too wide joints are detriments in several respects and for the following reasons:

The wider the joint the greater the receptacle for the retention of moisture and unsanitary matter.

The impact from wagon wheels is much severer with a wide joint than in the case of a narrow one, because the effect of a blow grows with the square of the velocity at which it is applied. But since the width of a gap determines the depth to which a wheel may enter it, therefore, the velocity which grows with the depth of the drop, must be correspondingly greater. In short, according to well established laws of dynamics, it follows that the destructive effect of the impact upon the edges of the blocks grows with the square of the velocity, and since this latter is a function of the width of the joint, the joint is a matter of paramount importance. To apply the foregoing reasoning to practice we may say, that of two cases in one of which the joint between blocks is a quarter inch wide and in the other it is half an inch wide, the destructive effect in the second case will be more than four times as great as in the former. To the prevalence of wide joints is due the rapid disintegration of our street pavements, of which their cobble-stone-like appearance is the necessary result.

Another bad feature arising from the same source is the impediment rough pavement puts in the way of vehicle travel. How detrimental this may be is obvious from the following:

Supposing the average width of a paving stone, including one joint, is 5 inches, and the stones be so worn that when a wagon wheel bears on two of them it sinks a quarter of an inch below their ridges. This necessitates lifting both wagon and load one-quarter of an inch high in order that the wheel may pass on, and as this performance must be repeated with

every wheel after every stone over which they travel, this work amounts to twelve lifts of a quarter of an inch each for every five feet of the progress of the vehicle, or three inches of a lift in five feet of travel, or five feet in 100 feet, and 50 feet in 1,000.

Assuming that a two-horse wagon weighs 2,000 pounds empty, and the load on it be 4,000 pounds, hence a total of 6,000 pounds. This weight is to be lifted 50 feet high while the team travels 1,000 feet. $50' \times 6,000$ pounds is equal to 300,000 foot pounds. Assuming further that the wagon progresses at the rate of 10,000 feet an hour, the lift of 50 feet has to be made once every six minutes, and therefore the energy spent in this work is 300,000 divided by six times 33,000 equal a trifle over $1\frac{1}{2}$ horse power. This quantity of energy is thus spent without benefit and it results only in destruction and noise and misery all around.

On a perfectly smooth track, as on street rails, there is scarcely any resistance beyond that from friction in the journals of the axles. Comparing the imported specimens of pavements with what we have in this line at home, the conviction forces itself upon the investigator that the best we produce now would hardly pass muster abroad.

The foreign "sets" appear to be *Syenite* (quartz, felspar and hornblende) which is a harder rock than *Granite* (quartz, felspar and mica.)

Granite belongs so far down that the sedimentary rock measures of Western Pennsylvania and others under them appearing east of the mountains and north of us, cover it miles in thickness; the carboniferous formation itself attaining a thickness of half a mile and extending down here at Pittsburg more than the 700 feet depth required to reach tide level at the river. So that granite does not appear at the surface nearer Pittsburg than on the lower Susquehanna river and on the Delaware river on the one side, and west of the Mississippi on the other, or at the north in Canada. Hornblendic rocks

do occur with the granite in this country but we have not heard of their being selected for making Belgian paving blocks.

Forty to sixty miles from Pittsburg to the south-east we reach the Chestnut Ridge and pass on to the Laurel Hill. On both flanks of these mountains we have the mountain limestone out-cropping at an elevation reaching 1,600 feet or more above tide level, and extending up the sides, from the main stream in any gap, hundreds of feet high. At the Conemaugh and the Youghiogheny 600 feet high.

It is a remarkably homogeneous, massive stratum of siliceous limestone fully 60 feet thick that has the Mauch Chunk Red Shale as its cover. They come in under the carboniferous formation—between the Salt sand of our gas and oil wells, above, and the Big Injun sand of the same, below. This mountain limestone furnishes the Ligonier blocks so extensively used on our city streets. It is accessible in every gap from Indiana and Cambria counties through Westmoreland, Somerset, and Fayette, south into West Virginia, and was quarried first for macadamizing the turnpikes that were built through these mountain gaps eighty to ninety years ago, and it is most extensively worked now at the Greensburg and Stoystown turnpike, on the Ligonier Valley railroad, in the gap of Loyalhanna Creek through Chestnut Ridge, where also building stones are made from it; power machinery being used for sawing and pneumatic tools for dressing them as well as compressed air drills in the general quarrying, and also crushers and sizing screens for making the fragments of the stone into ballast or macadam and the finer screenings used for surfacing roads.

Foreign granites used for paving range in specific gravity from 2.55 to 2.96. Ligonier block stone has a specific gravity of 2.68, from which its weight is found to be 167 pounds per cubic foot, and a square yard six inches deep to weigh 750 pounds; which may be about the weight of the paving seven

inches deep as laid here with its spaces in joints. The stones used weigh from 15 to 35 pounds, and there are about thirty-five of them in a yard. The crushing strength of this stone is about 2,800 pounds per square inch, and it is often as strong with the grain as across it, so that its use on end as well as on bed is quite warranted ordinarily.

We have from a paper read by Mr. James Morgan before the Liverpool Engineering Society, and remarks thereon, etc., some information up to 1894:

"The cost of first-class pavement sets $6\frac{1}{4}$ inches deep $3\frac{1}{4}$ inches wide, 5 to 8 inches long, upon 6 inches Portland cement concrete foundation, 12s 6d. ($3.12).

Second-class, 5 inches deep, $3\frac{1}{4}$ inches wide, 5 to 8 ins. long, upon $4\frac{1}{2}$ inches concrete foundation, - - -	10s 6d $2.62
Or four inch cubes on similar foundation, - - - -	9s 6d $2.36
Third-class, four inch cubes upon hand pitched rock foundation, - - - - - - - - -	8s 6d $2.10

"The concrete represented by ninety mixings in nine hours by one man, each mixing of one cubic foot of mortar resulting by adding the broken stone, in about $1\frac{3}{4}$ cubic feet of concrete or six cubic yards per day per man.

"Theoretically, for foothold when traffic is not excessively heavy, the surface width of the set should be three inches, yet since the improved method has been adopted in Liverpool the weights carried over it have so increased that loads on heavy traffic streets have often amounted to ten tons on four wheels, and more. The author would therefore prefer to use sets having a surface width of four inches; the depth of the most desirable set need not be more than $6\frac{1}{4}$ to $6\frac{1}{2}$ inches, while for leading thoroughfares of lighter traffic five inch sets have been used with advantage.

"For secondary industrial streets a very satisfactory pave-

ment has been extensively laid in Liverpool, consisting of four inch cube sets, also from Caernarvonshire quarries. The foundation in the streets of greater traffic being of Portland cement concrete five inches thick, and where traffic is trifling the sets are placed upon a well-rolled hand-broken rock foundation.

"Comparatively soft granites might be used where the traffic is light or the gradient steep, but for the streets of a great business section their use is not advisable. The question of the slipperiness of the more desirable sets is frequently brought forward in discussion upon pavements, but in the author's judgment there would be little ground for complaint if the surface were more thoroughly cleaned than is the case in towns where heavy traffic exists. What is really required is a condition of things approaching that of streets after a thunderstorm or heavy shower of rain, when all the mud is washed completely off the surface and the principal elements of slipperiness are removed.

"Statistics taken in London show that on asphalt, horses generally fall trying to stop a load, on wood they fall forward in trying to start a load, and on granite they fall indiscriminately but without such serious results as they suffer from when falling on asphalt or wood.

"Pitch pine carried the traffic in Euston Road, opposite Midland Station, for 12 years without being disturbed, and was only taken up last year when it was found that blocks in some places were only 1½ inches in depth, and moreover it cannot be said there was any general exhibition of rot in the blocks that were removed. There were some bad, of course, but not any considerable quantity." Quoting M. H. Percy Boulnois, president of the Liverpool Engineering Society, in the discussion of Mr. Morgan's paper:

"I do not know that I have any further remarks to make with the exception that I should like to conclude by telling you what I consider a perfect street pavement should be. I think it should first of all be impermeable to moisture; it should,

of course, be durable; it should have a foothold, and at the same time have ease of traction; it should be adaptable, if possible, to all gradients and also to all classes of traffic; it should be as noiseless as possible, and should not manufacture any mud or dust ; it should be easily cleansed, easily repaired, economical in the first cost and its maintenance, and uninfluenced by climatic changes; and lastly, I think it should have a good appearance."

For Pittsburg the specifications require: The stone blocks to be durable, uniform and approved quality, each measuring on the face of upper surface not less than eight nor more than fourteen inches in length, and not less than three and one-half nor more than four and one-half inches in width, and in depth not less than six nor more than seven inches. The blocks are to be dressed so as to present regular and true surfaces. All sides of the block must be free from depressions or projections, and all blocks which vary more than half an inch on each side from the rectangular shape will be rejected.

In Allegheny City, under the caption, Ligonier or Granite block pavements, the specifications require that the blocks must be the best quality of paving blocks, of a uniform quality, and each block must be a perfect prism. Blocks are to be laid in a good workman-like manner; both top and bottom to be level and free from rough projections; sides and ends of blocks are to be made so that they will fit perfectly together. Blocks are to be not less than three and one-half nor more than four and one-half inches wide, and not less than six nor more than seven inches deep. Blocks to be so laid that the joints or openings shall not exceed three-eighths of an inch.

In both cities the uniform rows are to be at right angles with the street, and to break joints at least two inches. In Europe the stones themselves are understood generally to be uniform, to fully break joints, and the rows to run at an angle of forty-five degrees with the line of the street.

The cost of Ligonier block pavements in Pittsburg with

eight inches concrete and two inches sand under them, and pitched joints, is at a fair price—two dollars and a half per square yard. Booth & Flinn are now carrying out a contract in the city of Allegheny at $1.24 per square yard; in this case there is no concrete foundation nor are the joints pitched. The foundation consists of eight inches of gravel.

At the quarry, blockmakers receive $16 per thousand regulation blocks, making them from pieces as blasted out, and earning from $1.50 to $3.00 per day. Much nicer blocks were turned out by the makers brought from Welsh and eastern quarries, and those who became expert under them ten years ago. Now, with the increased demand, the work is poorly executed by all kinds of men employed.

A much better quality of blocks could be obtained if the blockmakers were allowed a cent more per block—that is, $26 per thousand instead of $16, as now. This would increase the cost of the pavement 35 cents per square yard, as 35 blocks are, or should be, the average number to a square yard. If Ligonier stones were sawed instead of hammer-clipped, the cost, counting $\frac{3}{4}$ square foot of surface per block, would make a block worth five cents, and the blocks alone, without anything else, for a square yard $1.75.

Irregular stone pavement is made from the offal of the quarry. The stone per square yard of pavement laid is worth not over ten cents for hauling, and on board cars in the city they are worth twenty-five cents, counting the freight from the quarry to the city sixty cents per ton.

This material is called half-block, used in the Ligonier temporary pavement, and it might, by laborers with judgment, be set to have the stones supporting each other as well as be carefully bedded. But as laid here the pavement consists often of one-third dirt joint and two-thirds stone surface, and is worse than the old cobble stone which was close set and made firm by heavy beetle blows, so that ordinarily it could not be rutted.

The foreigner bestows more if less costly labor upon material that must cost more to get in the first place, and he lays lighter blocks on the streets that have less traffic.

There appears to be a means cheaply at hand in Pittsburg to have good foundations for paving without resorting to concrete. Blast furnace slag, if moistened when deposited, solidifies equal to any good cement, and will answer the purpose in every respect. The blast furnaces in the vicinity of Pittsburg produce about a thousand tons of such slag every twenty-four hours, and its disposal hampers them. They must ship it away by rail to get rid of it, and hence could afford to pay for having it taken off their hands.

Among the exhibits from Liverpool there is a specimen of street rail as used in that city. It is the invention of Mr. Jas. Morgan, city engineer at that place, and it consists of a short section of steel rail and a cast iron chair, with some other details, shown on a drawing accompanying this report. The obvious purpose of this design is to have street railway tracks so constructed that in the event of a necessary renewal of the rails on account of wear from service, no part of the track construction need be disturbed but the rails. As seen by the drawing referred to, this rail consists merely of a head with a groove to accommodate the flange of the car wheel, but not wide enough to admit the tire of any vehicle. This rail-head is borne on chairs fixed at intervals. The connection between rail and chair is made by means of a brass bolt, half an inch in diameter, with a countersunk head and slot for the application of a screw-driver; the head is sunk below the bottom of the groove in the rail, to protect it against wear from the car wheel flanges. The connection is not made directly with the chair, but with a wrought iron anchor; the brass bolt passes through a hole in said anchor, and is held thereto by a nut. This nut is of a peculiar shape, much larger than a standard nut for that size of a bolt, and it ends in a frustrated six-sided pyramid. The purpose of this is not obvious from the

service this nut renders. The anchor is made of a $\frac{3}{8}$ inch by two inch flat bar, and is bent in a manner resembling the sectional outlines of an ordinary T rail. In height it extends from bottom of rail to bottom of the concrete foundation under the pavement. The space within the rail chair is filled with pitch. This fulfills the double purpose of excluding moisture and preventing the nut from getting loose.

This specimen of street track rail and chair is not accompanied by any description from its inventor, from which information could be obtained in regard to several very important points bearing upon the fitness of this construction for the intended purpose, as for instance: spacing of the chairs; how to fill out the space under the rail where it is not supported by chairs; how are the joints constructed; and how about curve rails; and lastly, in case a rail is to be taken up and a new one to be put in its place; how are the holes laid out in the new rail in order that they shall come fair with the position of the nuts buried in the pitch, bearing in mind that these holes must be drilled and countersunk to suit the brass bolts, which are turned on the lathe?

We feel warranted in pursuing the subject of laying down street rails without wooden support.

Premising by stating facts of the Monier system for combining steel and cement in any structure, we then pass on to give a description of one kind of flat rail construction patented by Mr. Frederick Melber, of this city, who has wooden foundation ones for roads also, and has received the best official endorsement away from home.

The object of the Monier system "is to effect such a combination of the individual strengths of cement and iron that the compound shall be equally able to resist compressive as well as tensile strains, and this is to be achieved in a manner much more economical than if either of these materials was employed throughout in one and the same structure, be this an arch bridge, a slab, or any other piece of work in which both

kinds of stresses alternately or simultaneously occur. In accord with this end, iron rods or wires are imbedded in concrete at all points which might be subjected to tensile strains by any possible application of one or more loads. The results thereby attained are due to the remarkable affinity and consequent cohesion between cement and iron. According to a series of experiments, conducted by Professor Bauschinger, of the Polytechnic College of Munich, the union of these materials is so strong that with cement mortar of about six months' age it amounts to 600 pounds and over, for every square inch of surface in contact.

Since the ratio between compressive strength and tensile strength of cement six months old is approximately as 10 to 1, it is obvious that, though cement is an excellent material to stand compression, it is of moderate use where it is subject to tensile strains. It follows, therefore, if by some means its resistance to tension could be increased, its employment in engineering work, and no doubt in other directions, would grow beyond estimation.

This, then, is what the Monier system has accomplished. A further and very gratifying peculiarity of these two materials is that the expansion and contraction due to changes of temperature are, within a wide range, practically the same, and from European reports we learn that in all cases where heat is communicated to iron through the cement—that is to say, where cement envelops iron—the variations of temperature have no effect whatever upon the intimate bond of the materials combined. But more surprising yet is the information furnished by Mr. F. Melber, the inventor of the new road system, that the broad rails his system demands, and which he laid in a piece of experimental track, have not separated from their cement bedding, though they were exposed to the sun's rays during the whole of the open season of this year. This phenomenon is explained by the intimate combination of the cement with the rail ; the effect in this case is the same as that

from the modern methods of jointing the street rails either by welding or by casting iron around them. In both of these cases the expansion and contraction of the rails is entirely prevented. With the Melber system this result is attained through the cement, which, owing to being confined under ground and not exposed to the rays of the sun, remains in the condition due to its lower temperature, and by reason of the very great surface of rail and cement in contact and action, each square inch of rail is individually held fast and thereby prevented from expanding or separating. Thus there is not even a chance for the expansion to grow toward the ends of the rail, because provision is made throughout against its occurrence.

Mr. Melber furnishes, as introductory of the merits of his system, the following interesting matter on the general subject of roadway improvement:

"I would include, regardless of altering the location of roads, a low first cost of construction; greatest possible economy of maintenance; easy traction for least effort on part of animal or other power; least wear of road from traffic and from effect of the weather; resistance to formation of ruts, dust or mud, the causes of disintegration of stone roads; equal use by ordinary vehicles, horse or horseless, and street cars; construction in all sections of the country and on any soil; use for any stone or other material, including that unfit for the Macadam system, for instance.

"Aside from construction with timber and steel, a system now to be considered out of date here, I confine myself to all possible fundamental modes of combination with forms of stone, cement and steel.

"The principle is the mutual support of the parts presenting the surface of resistance to the impending action of a wheel under pressure—whether narrow or wide tread or a road roller—that the contact may not be at a point or mathematical line only from which would result crushing of hard material or

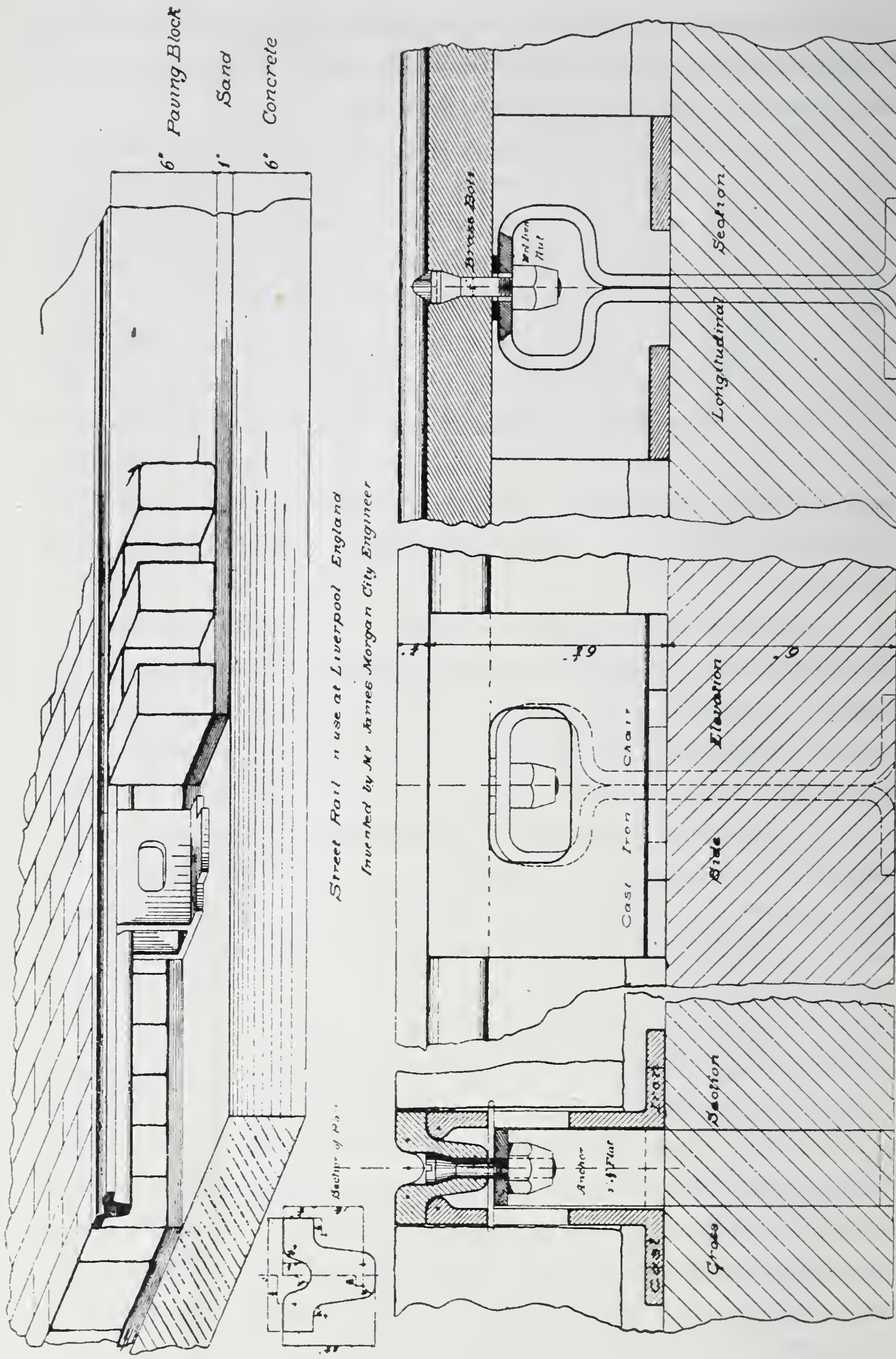
sinking of softer; the wheel pressure is taken up in all cases by steel stringers, of the inverted gutter shape, and transmitted to the comparatively larger surface of underlying more or less soft material where this is not concrete.

"To obviate the sliding of the wheel along the edge of the steel in approaching at an acute angle, there is an efficient way to hold up the adjacent road materials and bond them firmly with the steel, so that the wheels in approaching find a stone and no edge of steel to mount the steel stringers.

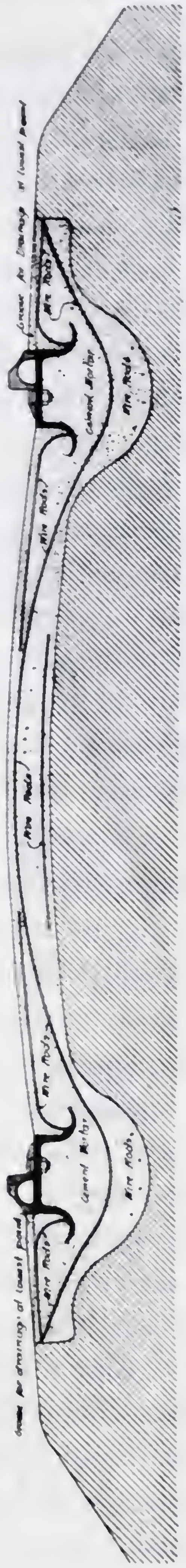
"I repeat from my report to the department in Washington, D. C., upon the traction advantages of my systems that as a result of twenty experiments on a section of road built by me, drawing a load ten times in one and ten times in the opposite direction, by means of a spring balance, the results compare with tests made by the department at Atlanta, and others, as follows:

"It takes 3.2 pounds to draw a ton on my roadway on the level; it takes eight pounds to pull the same load on an electric or steam railway track; from forty to seventy pounds on best Macadam, and from seventy to one hundred and ten pounds to pull the same load on a dry and hard earth road.

"I enumerate among other advantages that my system is cheaper than any good Macadam; my railroad cheaper than the one now in use—and eliminating the use of timber ties must exert a beneficial influence toward the preservation of the forests, so much sought by the government; the possible use of the highways in common with the railroads by the people, and power by these to detach the detachable railroad rails of a corporation, should commend itself to the people. The introduction of a cheap motor will enable the farmer, for instance, to not only haul his load and bring it home without breaking bulk, but also to do his field and farm work in a more efficient way than he can now—will gradually do away with the expensive and troublesome keeping of draft animals, and make him independent of a central power plant and the corporation."



Street Rail in use at Liverpool England
Invented by Mr James Morgan City Engineer



Melber Steel Highway System Design No 0

Of his accompanying drawings, numbered from 1 to 6 respectively, to illustrate the various methods according to which his roads may be carried out, the most characteristic among them is represented by cut here as drawing No. 6. In this the Monier system is applied according to strict scientific principles, similar to the rules followed in the construction of long span arches, which rule consists in this, that mere concrete is relied upon in those sections of the structure that cannot possibly come under any other but compressive stress, whereas parts subjected to tensile stresses are so provided with steel rods respectively wire, as to fully meet the effect of such stresses and thus render the whole capable to resist all strains that may come on it by reason of teams traveling upon the track, parallel but aside of the rails, crosswise or diagonally. As a further result of this combination the whole mass acts like a slab, always distributing the load upon a large underlying area, successfully shutting out water and preventing upheavals from frost that must otherwise occur.

General Roy Stone in charge of the Bureau of Road Inquiry, Department of Agriculture at Washington, it is reported has recommended the laying of an experimental mile of the Melber or similar road, the rails being made at Johnstown, Pa., and he is quoted as follows :

"I believe that the ultimate solution of our good roads problem lies in the steel highway. Undoubtedly the wearing surfaces of all highways are to be flat steel rails. There is no greater propriety or economy in running a wagon than there would be in running a railroad train over a rough surface of earth or stone. Horseless vehicles will undoubtedly develop metal roads. The saving in the expense of hauling would be from 50 to 80 per cent. Flat rails laid upon stringers should be the style of track used. They should be laid so that wheels might pass on to or off them without difficulty."

We find the bureau has been experimenting with flat rails on roads without the cement foundation, and has devised fish

plates at the joints of special construction—a double incline projection—to aid remounting in the event a heavy dray becomes dislodged from the track. And it would appear has had the question of turned up flange on the inside of rail instead of the outside, in abeyance; the idea probably being to favor the lateral support of gravel surface between the rails, have easier drainage and easier mounting. Mr. Abel Bliss, of New Lenox, Ill., has been experimenting and writes: "The rail I used is what is called channel 8 inches wide with a flange of 2 inches wide on either side, and the upward flange I used was ½ inch square steel riveted to the channel. The gravel between the rails packs the same as on any gravel road and is not likely to form into ridges. The bicycle riders say this track is all right. A horse is most likely to slip when pulling hard, and there is little occasion for them to tread on the rails, as there is room enough between them and there being no whipping of the tongue horses will travel closer together."

The reference to the lasting for twelve years of a wooden pavement in London, brings to mind the variety of them that were laid in Pittsburg about 1875.

For the foundation, the graded street was evenly rolled by a heavy steam roller, then ten inches of broken limestone spread over it and well packed by the steam roller, then two inches of gravel and sand were put on. In most cases the immediate foundation of the wooden blocks was a layer of pine boards one inch thick, and it turned out that this was detrimental and induced rot. One of the streets where the patent Miller pavement was kept from 1875 to 1893 is Lincoln avenue, E. E. This foundation was made as above, without the pine boards, the blocks were set directly upon the sand and gravel and afterwards brought to a compact bearing by the steam roller. But the characteristic feature of the Miller pavement lay in the shape of the blocks and their treatment preparatory to laying.

The blocks were sawn from squared white pine, 7 inches

thick, and of any convenient widths; the cutting being crosswise by a circular saw in lengths of 6 inches, but by the slanting of the saw table the kerf became oblique instead of square to the grain and rhomboidal pieces resulted; and by putting such a piece on the table in the position so that the faces which originally formed top and bottom sides of the timber stood vertically, another cut split the piece into two equal blocks, each with an end section that of an arch stone 6 inches deep. These blocks were set in pavements with their larger end surface downward, the grain being upright. They were set as close together in every way as their lower widths permitted. The slant of the saw table was so fixed that the width of a joint between two adjacent blocks was three-quarters of an inch.

The treatment of the blocks consisted in packing them into large wrought iron cylinders shaped like boilers; in diameter, about 6 feet, and in length about 30. The work of storing the blocks was expedited when expressly built trucks holding several thousand of them could be pushed into the vessel, which was horizontally placed. Such a cylinder, filled with blocks until all room was taken up, had a head piece bolted on and made tight; superheated steam being turned in until the whole charge was heated up and all moisture driven out of the blocks, and the water of condensation being then forced out, steam was turned off, the drain closed, and cold dead oil under a head allowed to fill the space.

The oil filtered through the pores of the wood to the heart of the block, leaving a dark scum outside, making it impervious to water and proof against rot. Our townsman, Dr. Otto Wuth, was the supervising chemist. He analyzed samples of every charge methodically; to have assurance of uniformity of treatment throughout, he entered in his note-book the position in the charge of each of a number of marked blocks. Picking out these marked blocks after the process

was completed and splitting every one of them, he could report after analysis that all the blocks had been thoroughly penetrated by the oil.

After the blocks were set the joints were filled out with a hot compound of gravel and pitch driven home by a specially shaped caulking implement.

Penn and Fifth avenues, E. E., had the boards which had been treated as the blocks were, and the paving lasted under the heavy travel about twelve years. Lincoln avenue, laid as above described, had lighter travel and was repaved after eighteen years.

A much-vaunted wooden block pavement, laid here and in other cities in the seventies, was the Nicholson. This was made of white pine blocks four inches thick, six inches deep and lengths according to widths of plank sawed up. They were set on pine boards laid over a gravel bedding, the rows being separated by a one-inch wooden strip nailed to the foot of the preceding row set.

Before putting down a block the board floor was mopped with hot pitchy tar, and the block dipped in hot tar. Both of these well meant operations had the effect of urging on the dry rot to which this pavement was doomed from the outstart, and they began to fail in from three to five years. There was paving also with round blocks of cedar and locust four to ten inches diameter according to size of tree cross cut, set on end and with halves and quarters where the interspaces were too large. The filling was gravel, without cement of any kind. All such pavements became cobbly and soon failed to give satisfaction.

So there was wood pavement and wood pavement, as there is asphalt and asphalt.

THERMAL CONDITION OF IRON AND STEEL UNDER STRESS, AND MEASUREMENT OF STRESS BY MEANS OF THERMO-ELECTRICITY.

BY C. A. P. TURNER, C. E.

While engineers have paid some little attention to determining the condition and intensity of internal stress by means of glass models and polarized light, the possibility of determining the stress in the metal they are using by measurement of the heat gained or lost when the stress is applied seems to have been entirely overlooked.

All are probably familiar with the fact that an elastic band, if suddenly stretched, grows warmer to a degree easily noted by touching the same to the lips.

Dr. Joule found that an iron wire one-fourth inch in diameter, under a load of 775 pounds, lost one-eighth of a degree in temperature, and most other substances lost heat upon being stretched. This discrepancy between iron and rubber was accounted for by Prof. W. Thomson on the theory that those substances grow cooler upon being stretched that are expanded by heat and vice versa.

Heating the rubber was found to contract it and the law appears to be established.

The writer is not aware of any experiments to utilize this law in the measurement of internal stress previous to his own, in which he found,

First—That stress can be quite accurately measured by the change in thermal condition of the piece, when the load is applied, if the stress does not exceed about five-eighths of the commercial elastic limit.

Second—That difference in the intensity of stresses of the same kind, though slight, occurring at two different points, can easily be detected by a modification of the same apparatus.

Third—For medium steel there appears to be a thermal limit, below which the test piece grows slightly and regularly cooler as the tensile stress is increased, and beyond which for a considerable space there is little change, until the commercial elastic limit (the drop of the beam) is reached, when heat is generated so rapidly that the curve is almost normal to the axis of absissas.

For compression also there is a thermal limit, below which the piece grows slowly and regularly warmer, as the stress is increased, until the thermal limit is reached, when there is a sudden and very rapid increase in the temperature.

The method of making these thermal measurements is quite simple, and gives promise of many valuable results to the worker in this field in which the writer has made but an humble beginning.

THE PLATE GIRDER.

As the subject of internal stress in the plate girder with stiffeners is incorrectly treated in the average text book, it is fitting that a correct analysis of this problem should be given as an illustration of the application of the thermal method. Let us first investigate the problem by the principles of applied mechanics, and then verify our deductions by physical measurements.

Both in "Lehrbuch der Ingenieur Mechanik," by Prof. Ritter, and in "Rankine's Applied Mechanics," will be found a very comprehensive treatment of the internal stress in solid beams of any cross section, that cross section remaining constant along the length of the beam. In these works it is conclusively shown that the lines of maximum or principal web stress at the neutral axis are tensile and compressive, acting at an angle of forty-five degrees with that axis and at ninety degrees with each other.

Now experience teaches us that where two or more shapes are well riveted together, they act under stress, by virtue of the shearing value and clamping action of the rivets, in almost

exactly the same manner as a solid rolled section of the form of that built up. Thus, we make up the top flanges of our girders of angles and plates and figure the sum of the areas of the shapes so riveted as carrying each its proportional part of the stress. Accordingly, if we have a built beam of a web plate and angle flanges, it will be in identically the same condition of internal stress that a rolled beam of the same section would be in, under the same load. The web would carry its share of the bending and nearly all of the shear.

To the limit necessary to withstand corrosion and give proper bearing for the rivets, economy requires as thin a web as possible to safely carry the vertical shear. For deep girders such a web would be in danger of failure by buckling, were it not stiffened by riveting on angle irons across it at interverals, generally equal to about the depth of the girder. When this is done, we no longer have a beam of constant cross section, but a ribbed beam, and the conclusions of Rankine and Ritter, with respect to beams of constant cross section, do not necessarily apply; certainly not, if we can prove the stiffener to be strained in compression.

Now the principle of applied mechanics upon which the whole mathematical theory of elasticity is based is "Hooke's Law," *Ut tensio sic vis.* Assume for the sake of the argument, that the condition of internal web stress remains the same with the stiffeners applied, and proceed to consider the case of a girder with inclined stiffeners; and we have the condition that the web plate is strained by a compressive stress along the length of the stiffener, and since the stiffener is rigidly attached to the plate by rivets, it is strained by an amount nearly equal to the strain or distortion of the plate. By Newton's Lex III, this localization of compressive stress in the stiffener must be balanced by an equivalent tensile stress in the plate from the bottom of that stiffener to the top of the next nearer the abutment, and we have for the line of principal stress the line diagram of a Warren girder, in which the

stiffeners are the compression web members. Further the action of the stiffener, in supporting the plate under and near it against lateral deflection, renders it better able to resist compressive stresses than the portion of the plate between the stiffeners, and would consequently receive more compression in strict accordance with the principle of rigidities, well worded by Prof. Johnson in "Modern Framed Structures," as follows: "Where there are two or more paths over which a load may travel to reach the support, the load divides itself among the several paths strictly in proportion to the rigidities of those paths."

The case of vertical stiffeners is similar, except that the portions of greatest rigidity under compression having changed direction, the lines of maximum compressive stress have changed in direction and intensity with them; the path of greatest rigidity in this case being the line diagram of a Pratt truss in which the flanges of our girder are the chords and the stiffeners the posts.

Let us now consider the deformation of a panel of the girder towards one end, when the girder is loaded, evidently one diagonal is shortened and one is lengthened. This may be largely accounted for by tensile stress alone, since if we stretch a square piece of elastic material, such as rubber, across diagonally opposite corners we would shorten the length of the other diagonal. The forces which are effective in resisting this deformation are compressive stress along one diagonal and tensile stress along the other, and we would naturally conclude that their proportionate magnitudes would be in the ratio of the relative ability of the plate to take these kinds of stress in their respective directions, and this ratio may be best determined by the application of Euler's formula. Having thus determined the amount of truss action, we may figure our stiffener with the filler and a certain portion of the plate under and near the stiffener, of sufficient strength to carry the post strain.

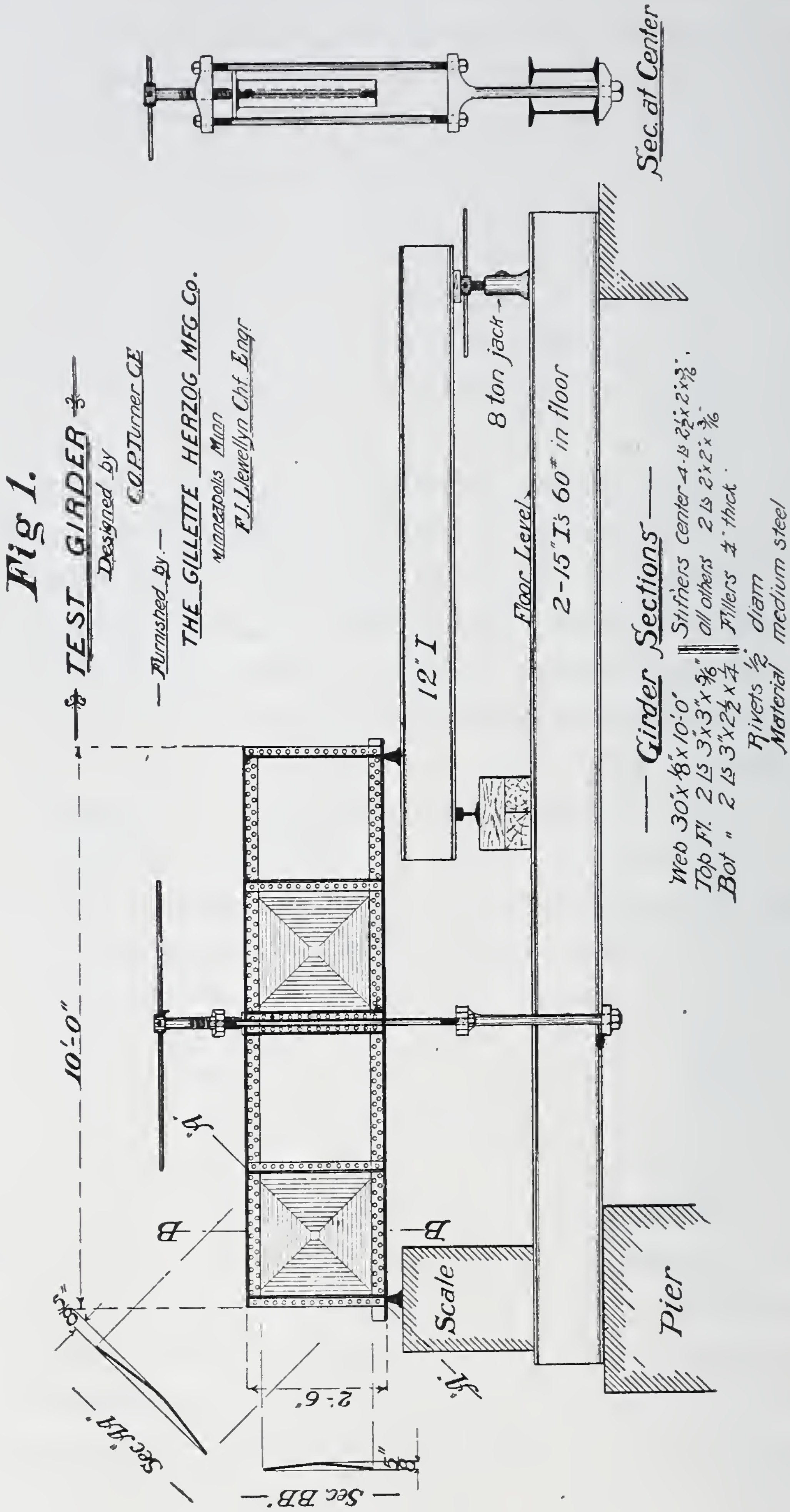


Fig 1.
TEST GIRDER
Designed by
C.O.P. Turner C.E.
Furnished by
THE GILLETTE HERZOG MFG Co.
Minneapolis Minn
F.J. Llewellyn Cht Engr
Sec. at Center
8 ton jack
12" I
Floor Level
2-15" I's 60# in floor
Girder Sections
Fillers ¼" thick
Rivets ½" diam
Material medium steel
10'-0"
2'-6"
Scale
Pier
Sec. AA
Sec. BB

Physical Analysis.—Practical experience having taught the writer the value of independent methods of verifying work, he proceeded as follows :

First—To so distort the web plate as to allow it to indicate the direction of the principal stress by its deflection.

This method was carried out by buckling the web five-eighths inch in the form of a very flat pyramid with the corners rounded off, the edges of the pyramid forming diagonals of the panel. Evidently were the stresses, tensile and compressive, distributed as in a beam of constant section, the lateral components of the tensile and compressive stresses would neutralize each other. If, however, the tensile stress is greatest, the buckle would spring in as the load is applied and go back as the load is removed. Under twenty-eight tons this spring of the buckle was one-eighth of an inch, and the buckle returned to its original shape as the stress was removed.

The load was applied by the screw lever at one end, and weighed off at the other end, as per Figure 1. A reaction of 28,000 pounds would thus be equivalent to twenty-eight tons at the center where the girder was bolted down. The spring of the buckled web seemed to be the same in the end panel and panel next the center, as would be expected, since the shear was the same in each.

Second—

BY THERMAL ANALYSIS.

The most advantageous means of making very delicate tests of change in temperature is that of thermo electricity, and was adopted.

The instruments used were the most sensitive made, a Melloni's antimony-bismuth thermopile, and a Thomson astatic reflecting galvanometer with the usual reading scale and telescope.

Before proceeding with the work upon the girder, it was necessary to establish that the galvanometer deflection was proportional to the stress for tension and compression ; and that

equal tensile and compressive stresses gave equal and reverse deflections for the same method of wiring. This we were very successful in doing, using thermal couples of a german silver wire and an iron wire about three inches long, soldered to the test piece and connecting our copper wires running to the galvanometer to these.

Then taking up the girder, we first set the galvanometer at a distance of about twelve feet from the girder, where we supposed it would not be disturbed by the application of the load to the girder; but by reversal of the connection it was shown that a part of our readings were due to floor deflection. A stand was then built on an engine bed in the laboratory, which is an isolated brick pier running down to a solid foundation, and we succeeded in getting a series of very satisfactory readings.

The first series of measurements were made on the neutral axis of the web at points near the stiffeners and in the centers of the panels. Marked heating effect was obtained in the plate near all stiffeners, and cooling effect in the center of all panels.

Heating effect denotes compression and cooling tension, as noted in the first part of the paper. These readings were tested by reversal of the connection, giving equal reverse deflections for the same load. The test for interpreting the meaning of a deflection was made by simply touching the tip of the finger to the opposite side of the web where the thermopile was placed, which would almost instantly give a large deflection. The direction of this deflection, if the same as the reading, would indicate heat; if the reverse, cooling effect or tension. The stiffeners were next examined, and all were found to be under compression, and one, owing to the fact that the girder was slightly warped, was found to be under compression and bending. In the outstanding leg on one side there was a small amount of tension, while on the other side we obtained about three times the deflection, indicating compression. With regard to the magnitude of the diagonal tensile stress in the webs,

evidently the compressive stress acting normal to the tensile stress would produce a heating effect that would partially offset the cooling effect of the tension, so that the galvanometer reading is only an indication of the difference in the intensities of these stresses. Were there no deflection at all on the neutral axis, we would conclude the tensile and compressive stresses were equal, as in a beam of constant section. Application of the thermopile to the neutral axis of our I beam lever, when under stress, gave no deflection, as should be the case under the common theory. Following out an excellent suggestion of Dr. H. T. Eddy, a series of readings were taken to determine the relative magnitude of stress in the top and bottom flanges. The measurements were taken at points vertically over each other in the center of the panels. The result shows stress in bottom flange, center panel, two-thirds of that in the top. In the end panel, half as much as in the top flange.

The conclusion to be derived from this work is that the custom of practical bridge builders in the use of vertical stiffeners is the correct practice from the standpoint of efficiency and economy, while the usual custom of proportioning flanges and spacing rivets is somewhat in error. The consideration of a portion of the web as effective flange area is justified by measurements made.

To obtain the maximum efficiency of the material, rivets should be spaced closer near the panel points and in intermediate stiffeners than is frequently done.

Columns.—A series of measurements made on small bars of sufficient length to act as columns, convinced the writer that a thermal analysis of the fibre stress of columns may be easily made under usual working loads. Various species of columns are coming into too general use, with batten plate web connections, the assumed economy of which will probably be shown by thermal analysis to lie solely in sliding up the scale of the working stress a notch or two nearer the danger limit.

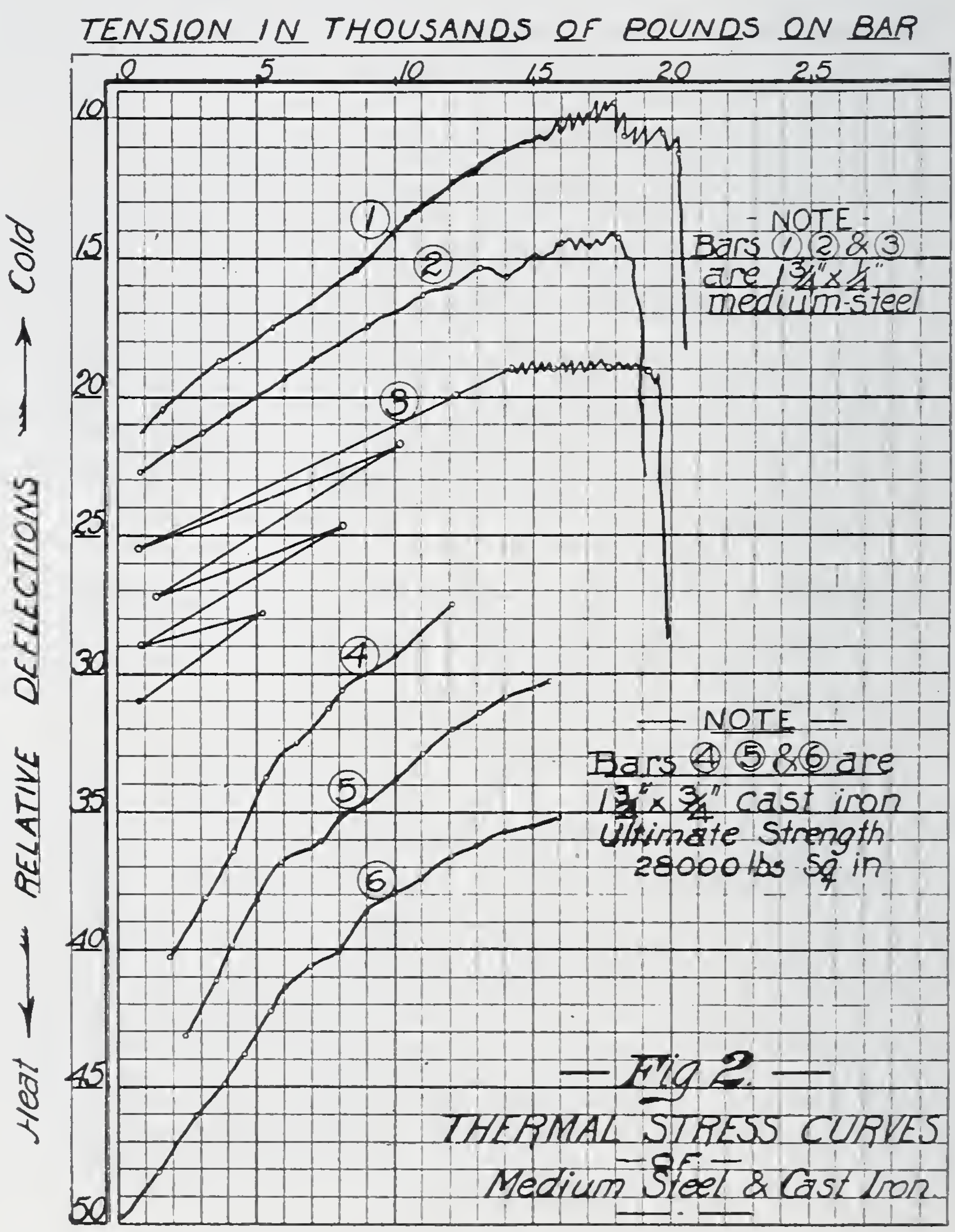
ELASTICITY OF STEEL.

The conditions of elasticity may be stated as follows:

A. Within the limit of elasticity the temperature change should be proportional to the stress.

B. The temperature change on removal of the stress should be equal and opposite to the change produced by application of the stress.

Condition A is almost perfectly fulfilled for a considerable range with the most homogeneous steel, and possibly to one-third or half this range in material of the same ultimate strength, but lacking in homogeneousness, such as the ordinary iron found in the market to-day.



— Fig 2. —

THERMAL STRESS CURVES — OF — Medium Steel & Cast Iron

Bars of cast iron, curves 4, 5 and 6, Fig. 2, fulfilled condition A when stretched only to about 4,500 pounds per square inch; and when strained beyond this point, if the tension was suddenly removed, the bar would evolve more heat than it lost by application of the stress. In testing these bars to destruction they were found to grow cooler until they broke without heat.

Tough and ductile material, such as mild or medium steel, does not immediately evolve as much heat as lost by application of the tensile stress when it is removed suddenly, but will in about a quarter to a half a minute. If we do not wait for

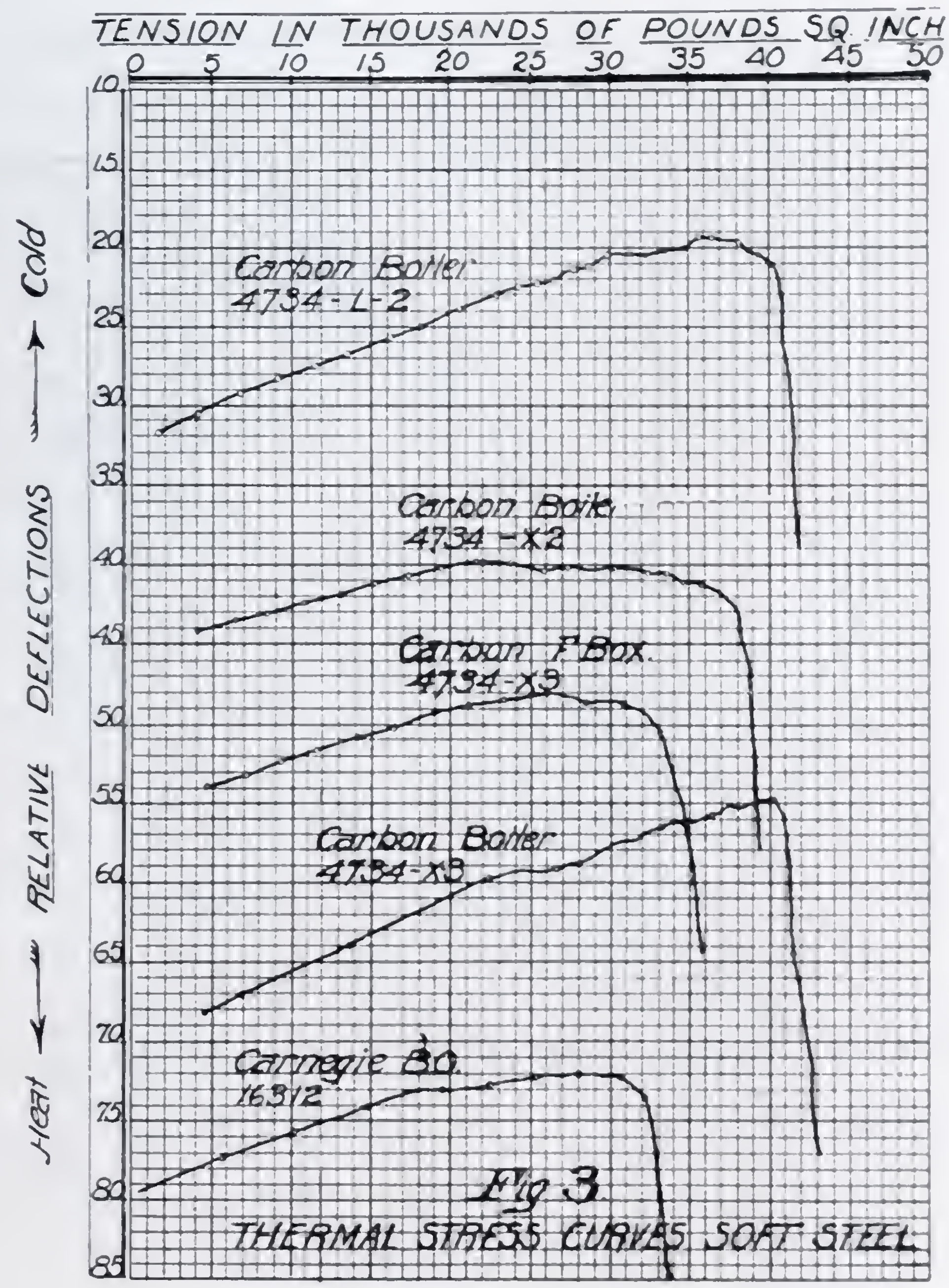


Fig 3.
THERMAL STRESS CURVES SOFT STEEL

it to do this and seesaw the stress, we may obtain the curve (3), Fig. 2. The thermal limit did not seem to be changed by this process, but the rapidity of application and removal of stress was not great enough to conclude that very rapid and repeated change of stress does not affect its position. A curve similar to 3 within the thermal limit may be obtained by applying and removing compression rapidly, the bar growing warmer instead of cooler as in 3.

Curves 1 and 2, Fig. 2, are from medium steel, ultimate strength sixty-five to seventy thousand pounds square inch; thermal elasticity, about 25,000 pounds square inch.

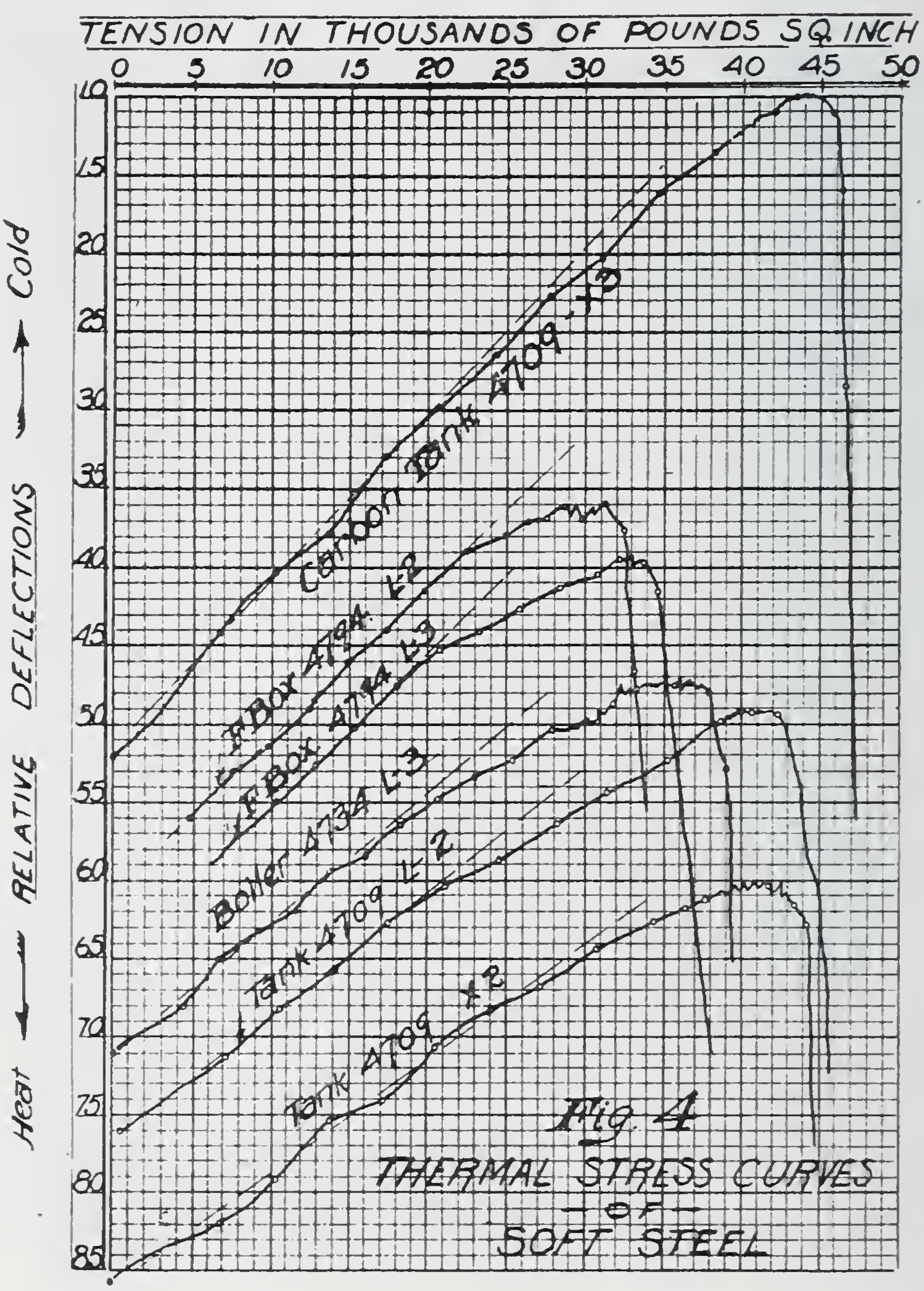


Fig. 3 shows curves of soft steel, composition, strength, etc., as per report of Mr. Harry J. Lewis, C. E., in table. The adjustment of the instrument, while less sensitive, was better than that used in taking the curves shown in Fig. 4, which are also soft steel. The thermal elasticity of these bars varies from 16 or 17 to 21 or 22,000 pounds per square inch.

All these curves are the result of only one set of readings. Since the material whose yield point is in the neighborhood of 40,000 pounds square inch would be little damaged by a small number of repetitions of stress to 22,000, we can determine the curves with great accuracy by making a number of tests to this point on the same bar.

The head of the machine was wrapped to prevent the thermal junction from being affected by the radiant heat of the gas jets, some ten feet distant, and from the operators.

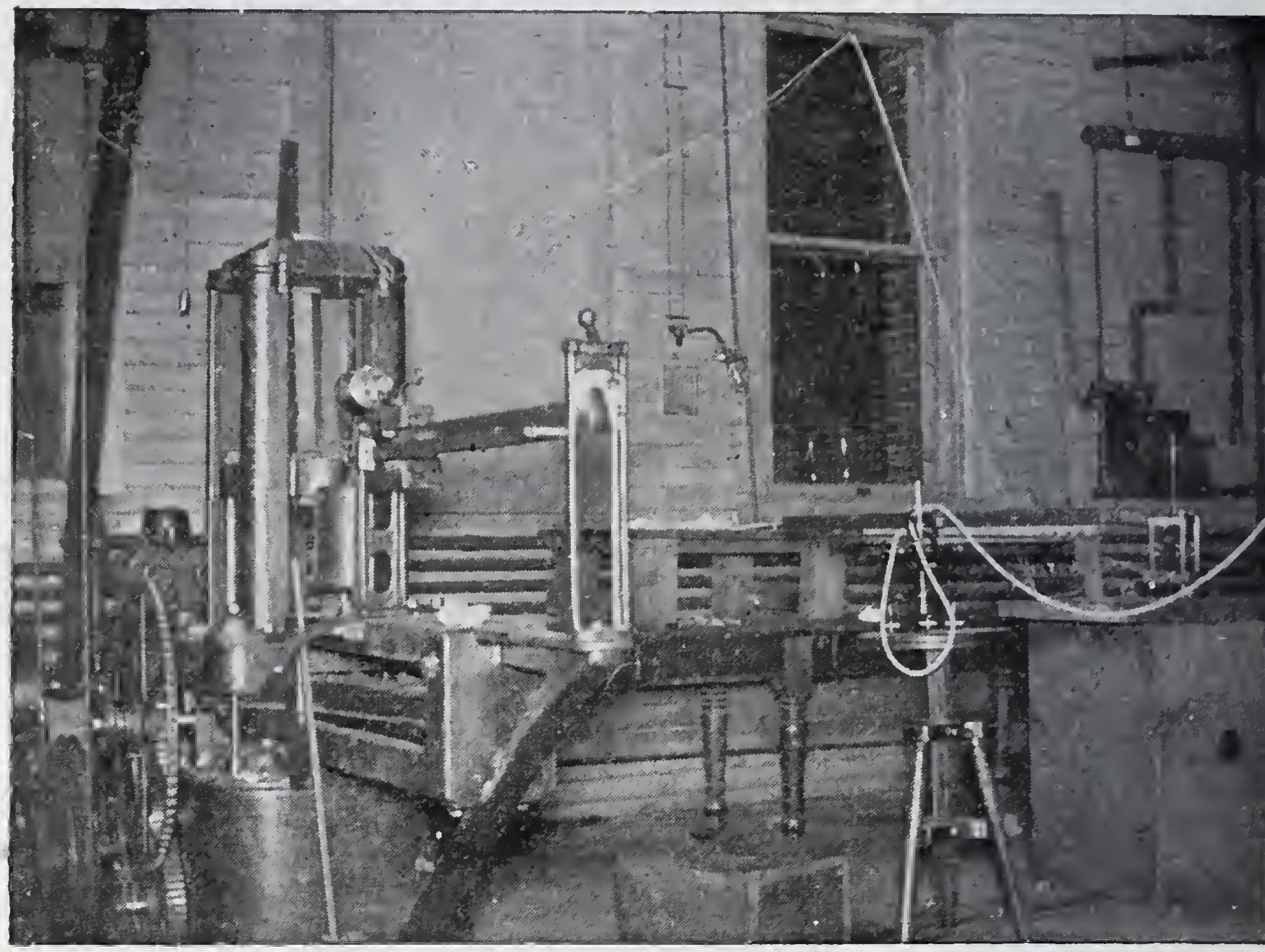
With the adjustment used in taking some of the curves of Fig. 4, there was considerable oscillation. The effect of oscillation is to make what would otherwise appear as a straight line a sinusoid, the axis of this sinusoid curving as the true thermal curve falls away from the straight line which it follows within the limit of elasticity.

The greatest error that may be involved in determining a thermal stress curve is that of imperfect alignment of the bar in the grips. The chucks should be well oiled so that they will adjust themselves readily to the line of pull, and the bar should be strained several times to an amount about one-quarter of the yield point, that they may have a chance to adjust themselves before taking readings; otherwise, that portion of the curve which should be a straight line will appear either convex or concave upward, dependent on which side of the piece the thermal junction is attached, and the alignment of the grips.

The galvanometer requires a firm pedestal, and after it has been properly adjusted, it requires little more time to take a series of readings than to test a bar in the usual manner.

No small amount of skill is requisite, however, in setting

up and properly adjusting the instrument. The adjustment should be carefully tested by reversal of the connection and the deflection should then be equal and opposite for the same stress, to those previously obtained.



A cut from a photograph taken of the apparatus used is shown in figure 5.

The galvanometer used was an Elliott Bros. instrument and could be used differentially, not only in determining the difference in magnitude of stress of the same kind at different points but also of different kinds at the time the stress is applied.

When the thermopile is used it should be properly hooded with non-conducting material, that it may not be affected by heat from without. The heat of the hand at a distance of a yard being sufficient to give an appreciable deflection.

As it requires considerable work to calibrate a galvanometer and as only the relative change in temperature was of

value for the work in hand, this was not attempted. Those who are interested in the actual temperature change in degree C may compute it very closely within the limit of elasticity by the formula derived by the great mathematician and physicist, Prof. William Thomson (Lord Kelvin), as follows :

$$H = \frac{t \quad p \quad e}{J \; S \; W}$$

Where H is the thermal increase in degree centigrade, the temperature centigrade from absolute zero, J the mechanical equivalent of the thermal unit, p the pressure applied in pounds, positive if compression, and negative if tension, e the longitudinal expansion per degree centigrade, S the specific heat and W the weight in pounds per foot in length of the bar. —(*Quarterly Math. Journal*, April, 1855.)

This formula has been experimentally verified by Dr. Joule.—(*Phil-Trans*, 1859.)

Its signification is that the heat evolved by compressing a solid is equivalent to the work required to compress the volume of it due to temperature.

Dr. Joule estimated with the instrument used by him that he could detect a temperature change of one eight thousand eight hundredth part of a degree C.

With the better galvanometer used by the writer probably more accurate work could be done and a change of perhaps one three thousandth part of a degree noted in ordinary work.

When iron or steel is stretched beyond the limit of elasticity a change begins to take place in the molecular structure, the material becomes harder and more brittle, the yield point and also the point where the bar ceases to grow cooler but evolves heat rapidly, is raised with the yield point, but the limit of elasticity appears to be lowered with each and every repetition of such stress. Further, when the number of repetitions of severe tensile stress above the limit of elasticity had been sufficient to complete in a measure this molecular change

in structure, the bars tested were found to present exactly the same thermal characteristics as cast iron, i. e., they grew cooler under increased stress until fracture occurred without heat at a point below the last heat limit noted.

This change in structure by mechanical strain requires the expenditure of a certain amount of energy, and the energy thus expended manifests itself in heat in exactly the same manner as that portion of the horse power of our engines used in overcoming the friction of bearings and moving parts.

The commencement of this change is then where the thermal stress curve commences to deviate from a straight line since at this point the heat evolved by this change prevents the bar from continuing to grow cooler at the previous rate. When the yield point is reached there is for a few seconds little elastic stretch and almost the entire work done is in producing permanent set and manifests itself in heat and we have the reversal of the thermal stress curve for tension and the extremely rapid production of heat compared with the previous regular increase for compression.

Some of the characteristics of the temporary change in molecular structure produced by mechanical strain and also the permanent change when the strain exceeds the limit of elasticity have been investigated by Prof. W. Thomson. See proceedings Royal Society, London, Vol. VII, 1854-55, p. 49; Phil Trans, 1856, British Association Reports, 1856, p. 17, in which he describes the methods and gives the results obtained in a series of experiments undertaken by him to determine the effects of mechanical strain, including the cases of longitudinal compression, lateral compression and extension, and in each case test both the temporary effects of strains within the elastic limits and the residual alteration in thermoelectric quality manifested after the cessation of the constraining force, when this had been so great as to give the substance a permanent set.

He summarizes his results as follows:

"The cycle of experiments has been so nearly completed for both temporary and permanent strains as to allow the author to conclude with certainty that the peculiar thermo-electric qualities induced are those of a crystal. Thus he finds that iron bars hardened by longitudinal compression have the reverse thermo-electric property to that discovered by Magnus in wires hardened by drawing, and that iron under lateral compression manifests the same thermo-electric property as the author had discovered in an iron wire under longitudinal stretching force. As regards iron, the general conclusion is that its thermo-electric quality when under pressure deviates from that of the unstrained metal towards bismuth for currents in the direction of the strain, and towards antimony for currents perpendicular to this direction. While for all those examined the residual thermo-electric effect of a permanent strain is the reverse of the temporary thermo-electric effect which subsists as long as the constraining force is kept applied. Other metals examined, zinc, brass, copper and steel, showed uniformly the reverse effect to that of iron when similarly treated. Curious results were also obtained by carefully annealing portions of wire which had been suddenly cooled and leaving the remaining parts unannealed. Iron and steel, copper and brass, have given decided indications in which the unannealed portions showed the same kind of thermo-electric effect as had been found to be produced by permanent lateral compression."

The fact that the residual effects of strain beyond the limits of elasticity are of reverse character for tension and compression, accounts for the more rapid wearing out of the material where this range of stress is from tension to compression.

As in all cases where experimental work has been done along a comparatively new line, the first results are not as accurate as those obtained later, with experience to guide the

conduct of the work. Thus the apparent thermal limit as shown by the curves will probably be found considerably too high, when the proper corrections for constant errors in measurement have been ascertained and applied.

The general form of the curves indicates that there is no general relation whatever between the fatigue of steel within the thermal limits and the wearing out of steel beyond the thermal limits of elasticity, the former being an inverse function of the homogeneity of the material, and the latter depending on the range of stress beyond the thermal limits and whether this range is from tension to compression.

Much attention has been given by our text-book writers to the treatment of suddenly applied loads and their effect, but, strange to say, in presenting the data upon which are based the maxima and minima formulae of proportioning, they neglect a careful discussion of the conditions of application of the loads under which the data was obtained.

The discussion of the effect of impact is beyond the scope of this paper, but the advantages of the thermal method of investigation in this field should not be overlooked.

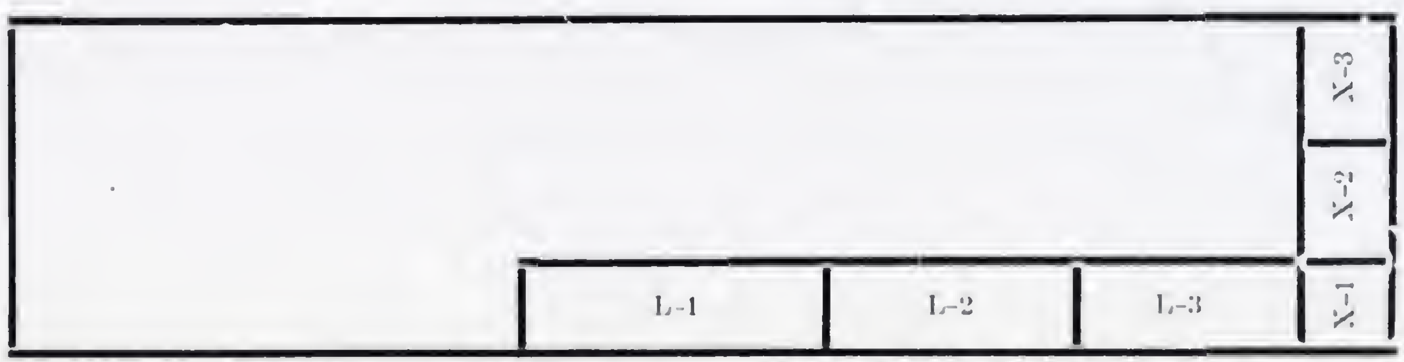
Without in anywise shifting the responsibility for the opinions advanced, the writer desires in conclusion to acknowledge the assistance received in his work by the members of the engineer staff of the Gillette-Herzog Manufacturing Company, and his indebtedness to the following gentlemen connected with the University of Minnesota: To Harry E. Smith, Professor of Mechanical Engineering, for the use of the testing laboratory; to Prof. Frederick S. Jones and Asst. Prof. Anthony Zeleny, of the Department of Physics, for practical suggestions and the use of apparatus; and to Messrs. Frank McIntyre and Bert G. Knight, scientific students.

TABLE OF TEST BARS, FURNISHED BY HARRY J. LEWIS, CIVIL ENGINEER.

Date of Test.	Blow or Cast.	Location.	Test From	Dimensions.	Area.	Elastic Limit. Pounds.	Elastic Limit. Lbs. per □″	Ult. Strength. Pounds.	Ult. Strength. Lbs. per □″
6-23-97	16312	....	4″ x 4″ L 12⁸	1.770x.510	.9027	33000	36560	54000	59820
6-24-97	4709	L-1	U. M. Pl.	1.690x.355	.6000	24600	41000	32500	54170
"	4709	X-1	Tank Stock.	1.690x.355	.6000	28100	46860	35000	53340
"	4794	L-1	Fire Box.	1.555x.485	.7542	29800	39520	45500	60340
"	4794	X-1	Fire Box.	1.690x.490	.8280	33500	40460	49200	59420
"	4734	L-1	Boiler.	1.700x.515	.8754	36000	41130	50300	57470
"	4734	X-1	Boiler.	1.700x.545	.9264	40000	43180	56800	61320

Elongation. 8 in.	Elongation. Per Ct.	Reduction. Dimensions.	Reduction. Area.	Reduction. Per Ct.	Fracture.	Analysis. Carbon	Analysis. Phos.	Analysis. Man.	Analysis. Sul.	Remarks.
2.56	32.0	1.280x.315	.4032	55.3	Cup	.21	.016	.37	.023	Carnegie Basic Open Hearth.
2.16	27.0	1.300x.150	.1950	69.1	Cup	.12	.068	.32	.021	Carbon Plates.
1.92	24.0	1.335x.235	.3136	47.7	½Cup	.12	.068	.32	.021	
2.30	28.7	1.155x.315	.3638	51.7	45°	.21	.035	.35	.028	
2.25	28 1	1.290x.330	.4257	48.6	45°	.21	.035	.35	.028	
2.28	28 5	1.280x.300	.3840	56.1	45°	.21	.033	.38	.022	
1.76	22.0	1.275x.345	.4339	52.5	45°	.21	.033	.38	.022	

Top of Ingot.



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L-1 and X-1—Pulled Here. L-2, L-3 and X-2, X-3—Sent.

DISCUSSION OF MR. TURNER'S PAPER.

Mr. H. J. Lewis—This paper is interesting both from a theoretical and practical standpoint. For a long time we have known that the ordinary tensile strength testing machine did not determine, of itself, the point to which metal could be worked with safety. In an empirical way we know that when metal is worked under vibrating loads, often repeated, at strains which exceed one-half the commercial elastic limit, its molecular composition is liable to change in the direction of chrystallization. Heretofore there has been no definite way of determining this point in an experimental way on test specimens.

The investigations of Mr. Turner would lead us to hope that a cheap and comparatively convenient way of determining this point of beginning of molecular change may soon be available. Based on the relations between heat and volume of material there is nothing new or hard to understand, and when the proper coefficients shall be determined for correcting the necessary errors of observation and for translating the galvanometer deflections into actual temperatures, we should have a valuable addition to our means of testing materials.

Mr. Lewis then drew a curve upon the board, showing the relation between stress and galvanometer deflection, and showed how the true elastic limit could be obtained from it.

Mr. Davison—The elastic limit you give there is about the proportion of one-half of the commercial elastic limit?

Mr. Lewis—As Mr. Turner notes in his experiments, it would be about five-eighths, but he thinks there are some errors in the apparatus which would bring it down to about one-half of the commercial elastic limit. That seems to be the practical side of it. I am not able to go into the matter theoretically, but would leave that for Prof. Fessenden or Mr. Fisher. This has been a very interesting paper to me. It deals with matters, some of which we have had knowledge of

before, but with which we have only been able to deal in an empirical manner. According to Mr. Turner's theories, we now have a little more light thrown upon them.

Prof. Fessenden—It seems to me the method of the writer should be able to be put to good practical use in two important cases.

First, in determining the stresses in members of a rigid structure. In certain cases, where a lot of beams are riveted together, there is some doubt how the stress is distributed when a load comes on the structure, i. e., just how the effect of the riveting effects the distribution. The load would have to be applied quickly, so that readings could be taken before the iron had cooled down.

Secondly, in determining the effect of moving loads, it is quite possible that in bridges, when a train passes over them, stresses are set up in some members, due to inertia effects, which may be quite large and quite different from the stresses with a steady load.

For the benefit of any members who may wish to take up this question, I would say that recent advances in electrical instruments render it possible to get very sensitive D'Arsowal galvanometers, capable of being used in this work, and at a very low cost. The wire must be applied to the specimen in such a way as to be sure that it is the stretching of the iron and not that of the solder which gives the heat.

Mr. Estrada—I regret exceedingly that I did not receive a copy of Mr. Turner's paper early enough to have read it more carefully than I have. The results of Mr. Turner's experiments are very interesting, and if his conclusions are correct, his method for studying and determining the nature of stresses in structures will prove of great value to the engineering profession.

The lowering of the temperature of a specimen by the application of a tensile stress is a point which interests me greatly. I have tried to account for it, but can't unless it be

that the volume of a specimen is increased under tension, and if such is the case with an iron or steel rod, I fail to see why the same should not be true of a gum band.

I would like to know what the ends of the curved lines represent? Are these the breaking points or the end of the experiment for each rod?

MR. LEWIS—Those curves only represent the carrying of the stress a little beyond the curve of the commercial elastic limit.

MR. ESTRADA—Concerning the elastic limit, I think Mr. Turner is rather indefinite. He should have defined the term. I notice that he speaks of "the commercial elastic limit"; that term has not any scientific value.

If his conclusions are correct, his method admits of an indefinite number of applications of great practical value.

Will a specimen attain the temperature of the surrounding bodies soon after it has been subjected to tension?

MR. DAVISON—Can you answer, Mr. Lewis, the question of Mr. Estrada regarding the temperature of the steel under stress?

MR. LEWIS—I think the temperature of the steel would gradually return to the temperature of the surrounding air.

MR. ESTRADA—The statement is made that when the specimen is compressed its temperature is increased, and when the compression is diminished its temperature is lowered. Now, is that absolutely so? Is that statement correct?

MR. LEWIS — I should say that was true in a relative sense. At the same time I think that the test specimen would gradually drift back to the temperature of the surrounding air. For the brief time of the experiment, and with the extreme delicacy of the instrument, I think the changes in the temperature are as were stated by Mr. Turner. A slight rise in temperature indicated by this means, is just the same as a rise in temperature caused by other means. The material will gradually drift back to the same temperature as the surrounding air.

Mr. Davison—I understand that if you apply this apparatus to a bridge—to a member of a bridge—you could not determine the stress due to a dead load, but only to the stress of a load suddenly applied; that is, the galvanometer would indicate the stress due to a live load, but not the stress caused by a dead load.

Mr. Lewis—I think that it is stated somewhere in the paper that this apparatus is only for the determination of relative changes due to live stress. It is purely a relative apparatus. The point that you have made is one which Mr. Turner and I have taken up by correspondence. I think so far as the dead load is concerned, that the apparatus would be of little value, but on the other hand that we should be able to determine with considerable accuracy the amount of stress caused by a live load.

Mr. Davison—Mr. Estrada, you would consider the machine more valuable if it could measure both the stress of a live load and the stress of a dead load, would you not?

Mr. Estrada—I certainly would consider it more valuable. If that load is maintained, will the temperature remain reduced or will it assume the temperature of the surrounding bodies?

Mr. Lewis—I feel sure that it would resume the temperature of the surrounding bodies. I think you can only use this instrument to determine the variation caused by the stress at the time it is applied. I am very sorry that Mr. Turner is not here this evening, as there are some electrical points which need to be brought out more clearly. The readings which were obtained had to be made within a given time, and that time must be as short as possible, as there would be considerable tendency to resume the temperature of the surrounding area, and thus a false reading is liable to be given. I should think the proper way to make the readings would be to subject the piece to the pressure of perhaps 10,000 pounds and mark your readings. Then allow the piece to go back

to the normal. Then subject it to a strain of 15,000 pounds. I think the experiments should be made in this way, always allowing the piece to return entirely to the normal, rather than to make a series of almost continuous experiments. There is one point in regard to making these tests, and that is that while it is comparatively easy to make approximately correct tests in the laboratory, it would be very hard to do it in the open air.

Mr. Ralph Croker, Jr.—I think it is very plain in this case heat is induced by work, by putting on the load, the same as heat is induced by the hammer. The heat will undoubtedly radiate away until you strike another blow, or until you apply another load. The moment the piece remains at rest, it must lose its temperature in the surrounding air.

Mr. Estrada—Why is the temperature raised in compression and not in tension? Why does the metal cool in one case, and why in another does it become warm?

Prof. Fessenden—As a metal is heated it expands, and as it is cooled it contracts, and if we produce expansion by tension it is but natural that its temperature should fall as long as we stay within the limits of perfect elasticity. In the same manner compression should produce heat. This does not amount to a proof, but it is possible to prove it very rigidly, but it is too long to go into to-night.

As soon as molecular change and flow in the metal begins, heat is evolved in both tension and compression.

(Illustrates from Mr. Lewis' diagram on board.) The true curve of cooling due to expansion by stretching is here masked by the curve of heating due to flow. When they equal each other the heating is zero. Hence we see that the true elastic limit is really below the point marked by Mr. Turner. He has taken the point at the top of the curve, where the cooling due to a small increment of stretch is just neutralized by the heat given by the flow of metal corresponding to the increment of stress, consequently the true limit, if what I hold be true, is where the curve begins to bend.

Mr. Davison—Mr. Estrada goes back of that and wants to know why the thermal results are not the same in compression as in extension; that is, the force being applied, why in the one case is the temperature raised, and in the other lowered?

Mr. Lewis—That is only true within the limits of perfect elasticity. It is strictly in accordance with the laws of expansion and contraction by heat, and the laws of heat. Beyond that limit both forces tend to heat, whether the force be tension or compression. Both of them heat after that limit is passed.

Mr. Deischer—If a specimen is subject to the action of a force that tends to compress or to stretch it beyond its limit of elasticity, only that portion of the energy employed will produce a change in temperature which was applied from the point on where the elastic limit was reached, because the change in the shape of the specimen, brought about during this latter period, is permanent, and it might as well have been produced by the hammering, rolling or squeezing process, under the performance of any one of which heat would have been excited in that specimen, because the energy thus spent was really spent, that is, in producing work. But it appears that the case is different where the change does not exceed the limit of elasticity, within which the behavior of the specimen is to be considered the same as that of a spring. In this instance the stretch is not permanent, but only temporary, for as soon as the action of the external energy ceases, the specimen assumes its former length and shape. Thus the energy employed in producing the change was not converted into work, else there would be an end to further action; but it was converted into potential energy, and this brought about the reaction, after the termination of the external force. For this reason, there should not occur a change in temperature, in either sense, while the force applied remains within the limit of elasticity; on the other hand, an increase of temperature will inevitably occur after that limit is exceeded.

Mr. Fisher—I think that perhaps it depends entirely upon the temporary displacement of the molecules in the material. If you make a *solution* of two materials that have no chemical affinity, the mixture becomes cooler. If you make a chemical compound of substances that have an affinity for each other, heat is evolved during the process In this case, at least, you get either cooling or warming effects by molecular displacement. Now I do not pretend to say that it is a molecular action in metals which produces the temperature effect spoken of by Mr. Turner, but only that it may be. This molecular action might give us a cooling effect in the one case, and an increased temperature in the other.

Mr. Estrada—So far as testing I-bars is concerned, I think there are many of us who can mark the exact spot where it will break. I have done it, many times. It is done by marking the hottest place.

Mr. Lewis—That is not the phenomenon Mr. Turner is working upon, for if this matter could be determined by the hand there would be no necessity for using such delicate instruments as the galvanometer and the thermopile.

The changes in temperature are exceedingly slight, and can only be measured by an instrument capable of registering such extremely minute changes. Of course, all of us who are accustomed to making tests of the strength of steel, know that there are such things as hard and soft spots, and hot places, while the metal is under destructive stress, and that these spots are preceptible to the hand. But the changes to which Mr. Turner refers occur before the true elastic limit is reached, and before the variation in the temperature is sufficient to become perceptible to the hand.

It is very true that the changes spoken of by Mr. Turner are very slight, but the thermopile is capable of registering every change of temperature, no matter how slight. For instance, the thermopile will respond to the heat radiated from the hand while it is not more than a yard distant. I, for one,

have a great deal of faith in the paper, and will be glad to see the subject more fully discussed.

A MEMBER—Do I understand that the changes spoken of by Mr. Turner indicate the changes of temperature in degrees centigrade within the limit of commercial elasticity?

MR. LEWIS—No, sir, the readings do not refer to degrees centigrade, but are proportional readings on the galvanometer arc. The actual difference in degrees would vary, perhaps, from 1-100 to 1-10 of a degree.

MR. DAVISON—There is no doubt about the correctness of the reading obtained by the galvanometer; but I do not think that the one question asked by Mr. Estrada has been answered yet. He wishes to know, if I understand him, why different forces, such as compression and extension actually produce, in one case a raised temperature, and in the other case a lowered temperature.

MR. ESTRADA—I would also like to know if there is any change in the volume of the metal under stress?

PROF. FESSENDEN—Under tension the volume is always increased, while under compression, the volume is actually less; that is, there is a diminution of the cubic contents of the piece. Poissons' ratio gives the side contraction as one-fourth the elongation, when strained, and though Lord Kelvin thinks there is no relation, he has been misled, as I have pointed out elsewhere,* in his deductions from certain experiments, and the ratio is probably nearly true for homogeneous metals. So that the actual cubic contents of the piece is really increased by subjecting it to tension, while if pressure is applied, the actual cubic contents of the piece is diminished.

Now whilst in some respests the properties of gases and solids differ, in this respect they agree. The subject is a very difficult one, but has been worked out by Prof. J. J. Thomson in his book on "Dynamics applied to Physics and Chemistry," or at any rate, can be deduced from the equations given therein.

* Journal Franklin Institute, February, 1896.

(He then illustrated on the board, using the analogy of a gas compressed in a cylinder, the effect of allowing the iron to cool after extension, and before relieving the stress. The analogy was justified by showing that the rigidity, Young's modulus, and tenacity could be explained as due to the action of molecular forces depending upon the sizes of the atoms, and the following formulas were given :

$$\left.\begin{array}{l} \text{Rigidity} = \dfrac{28\times 10^{12}\times(\text{density})^2}{(\text{atomic weight})^2} \\ \text{Young's modulus} = \dfrac{78\times 10^{12}\times(\text{density})^2}{(\text{atomic weight})^2} \end{array}\right\} \text{in absolute C. G. S. units.}$$

$$\text{Tensile strength In kilogrammes for wire 1 m. m. in diameter} = \frac{\text{absolute temperature of melting pt.}\times\sqrt[3]{(\text{d'y})^4}}{1.92\times\sqrt[3]{(\text{atm. wt.})^4}}$$

Illustrations were given showing that these formulas held true to within the limits of the experimental error for the pure metals, and that by a modification they could be applied to alloys.)

Upon motion of Mr. Lewis, a vote of thanks to Mr. Turner for his exceedingly interesting and valuable paper was passed, after which, the meeting adjourned.

ERRATA SLIP.

October proceedings, page 411.

$$\left.\begin{array}{l}\text{Tensile strength}\\ \text{in kilogrammes}\\ \text{for wire 1 m.m.}\\ \text{in diameter.}\end{array}\right\} = \frac{\text{absolute temperature of melting point}\times\sqrt[3]{(\text{density.})^4}}{1.92\times\sqrt[3]{(\text{atomic weight.})^4}}$$

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the society, 410 Penn avenue, Pittsburg, Pa., Tuesday evening, October 19, 1897, the vice president, Mr. George S. Davison, being in the chair. The meeting was called to order at 8.25, about thirty-five members and visitors being present.

The minutes of the preceding meeting were read and approved.

The names of the following applicants for membership were read by the secretary:

William E. Corey, general superintendent; Vernon R. Covell, civil engineer; Alva C. Dinkey, superintendent; Abe S. Isaacs, chemist; Brabazon Rutherford, electrical engineer; Paul S. Whitman, draughtsman.

Mr. Davison stated that since the last meeting there had been over three hundred dollars turned into the treasury, but that there were still some one hundred and twenty-five members in arrears to the extent of about fifteen hundred dollars, and that the Board of Directors would make a strong effort to have this money paid into the treasury in the near future. Of the one hundred and twenty-five members in arrears, he stated that about one-half were in arrears for the present year only, and that while this was not very far back, at the same time the money would do the society a great deal of good when it came into its possession, and he trusted that the treasurer would be in receipt of the dues from these delinquent members in the very near future.

The Committee on Power reported progress.

There being no further business, the regular paper of the evening, "Thermal Condition of Iron and Steel under Stress, and Measurement of Stress by means of Thermo-Electricity," by C. A. P. Turner, C. E., was read by Mr. H. J. Lewis.

After discussing this paper (pages 403 to 411), the meeting adjourned.

REGINALD A. FESSENDEN,
Secretary.

MEETING OF THE CHEMICAL SECTION.

PITTSBURG, PA., Oct. 21, 1897.

The regular monthly meeting of the Chemical Section was held in the Lecture Room of the Engineers' Society, October 21st, 1897. W. E. Garrigues presided. Attendance, 16.

The minutes of the last regular meeting were read and approved.

J. O. Handy, for the Committee on Literature, called attention of the Section to a number of recent papers.

W. E. Garrigues read the paper for the evening on the Analysis of Bearing Metal Alloys.

After discussion of the paper the Section adjourned at 10 P. M.

A. G. McKENNA,
Secretary C. S.

THE ANALYSIS OF BEARING-METAL ALLOYS, WITH A NEW VOLUMETRIC METHOD FOR DETERMINING COPPER.

BY W. E. GARRIGUES.

Judging by the number of articles that continue to appear from year to year in chemical journals, elaborating more or less complete schemes for the analysis of these alloys, the subject is still a timely one for discussion. There is furthermore small likelihood that this apparent interest will lag in the near future at least, owing to the evident fact—and it is one that must not be lost sight of in passing judgment on the merit of such a combination of methods for separation and determination as the present paper deals with—that we are not considering a material capable of being handled like steel, where accurate methods have been found for ascertaining the quantity of almost each element present without the necessity of first removing three or four others from solution.

In the light of our present knowledge of the chemical deportment of the metals of the hydrogen sulphide and ammonium sulphide groups, all methods which even approach accuracy must of necessity be comparatively tedious. Not alone is it essential in almost every case to free a solution from interfering elements to reach the one sought but in very many instances it is all but impossible to get the former out of the way without sustaining loss of the latter. Add to this the manipulative difficulties such as the washing of slimy precipitates that persist in passing the filter medium, and those that in coming down occlude non-volatile salts used as re-agents or sustain loss in ignition through reduction and volatilization—there is certainly sufficient difficulty remaining to interest many of us for years to come.

The present paper is not written so much with the object of presenting innovations that conduce to speed as to discuss some of the inaccuracies in very commonly used processes and to consider means for overcoming them, even though at times additional labor may be involved. Of late years the art of successfully working scrap has reached such perfection that it is probably not an error to assume that the greater part of the metal in alloy bearings now in use, was at one time doing duty along a varied line reaching from wash boiler bottoms to tea packages. The inevitable result is that the subject has grown still more intricate from the analysts point of view, the range of elements existing in small percentages being greater.

The alloys considered are bronze, brass, and white metal, composed of copper, tin, antimony, lead, zinc, iron, phosphorus and arsenic.

The advantage of a qualitative analysis previous to beginning the analysis proper has been often dwelt upon, and there is little doubt but that it almost invariably repays the trouble ten fold. In the scheme to be outlined here it is particularly desirous to know beforehand if antimony, iron, zinc, and arsenic are absent, for which we have found the following proceedure easy and good:

The sample is oxidized with nitric acid, and evaporated dry, boiled with a little dilute nitric acid, the residue filtered out and washed.

Antimony: Ignite a portion of the residue intensely, boil with strong hydrochloric acid and dilute with an equal volume of water. Filter and add considerable water when a white precipitate indicates antimony. Confirm by orange hydrogen sulphide precipitate.

Arsenic and Iron: The remaining portion of the residue is warmed with a little caustic soda solution and dissolved by the further addition of alkali sulphide and heating. The black residue is removed by filtration and treated for iron by any suitable method. In the alkaline filtrate arsenic is precipitated with ammonia and magnesia mixture, the precipitate filtered out and dissolved in hydrochloric acid, which solution is boiled with sulphurous acid and then saturated with hydrogen sulphide, when the arsenic if present is obtained as sulphide.

Zinc: The filtrate from the nitric acid insoluble residue is saturated with hydrogen sulphide, the filtrate mixed with one tenth its volume of strong hydrochloric acid and potassium ferrocyanide added, when zinc is indicated by a white precipitate of the ferrocyanide.

Quite a large amount of the sample should be used as otherwise antimony may all pass into the nitric acid filtrate and thus escape detection. The ignited stannic oxide is entirely insoluble in the boiling hydrochloric acid, while sufficient antimony dissolves to give ample reactions. The large amount of hydrochloric acid is added previous to testing for zinc to prevent the coprecipitation of any lead that may have escaped coming down as a result of the hydrogen sulphide treatment.

Coming now to the quantitative part of our subject, we have to consider first,

THE DETERMINATION OF SINGLE ELEMENTS.

Zinc, when present in fairly large quantity, and an absolutely correct determination is not required, can be very con-

veniently measured by titration with standard potassium ferrocyanide but in smaller amounts a gravimetric method is preferable. For the details of the process see Stone, J. A. C. S. 17. 413. The end point is marked by an immediate green color with cobalt nitrate.

Stone directs that the volume of standard liquor necessary to give the end reaction be determined by a blank experiment, and that this amount be subtracted from each titration. This statement we have been entirely unable to verify, as witness the following set of titrations of varying amounts of the same solution of zinc chloride :

c.c. $ZnCl_2$.	c.c. K4FeCy6,	Total %	Blank %
0	1.5		
5	6.0	30.0	22.5
10	11.8	29.5	25.7
12.5	14.6	29.2	26.2
15	17.5	29.15	26.6
25	29.2	29.2	27.7

Total per cent. column is figured on the assumption that the highest titration is per cent. zinc, the lower titrations then being multiplied to equal the same volume of zinc chloride used—no blank being substracted. Figures in blank per cent. column are obtained in the same manner except that the blank is in each case subtracted. It will be noticed that the figures in the latter column are anything but uniform among themselves. To get the best results the standard solution should be titrated against a known zinc solution of the same strength as the sample under examination. In applying the process absence of copper and iron is essential.

When the conditions of precipitation are fully understood one of the neatest and most accurate analytical processes is the determination of zinc as phosphate. All metals, inclusive of alkalis, should be absent.

The solution should be exactly neutralized with hydrochloric acid or ammonia, as the case may be, using methyl

orange as indicator—unless the liquid contains acetic acid, in which case no further inconvenience results except that litmus is substituted for methyl orange. A very large excess of ammonium phosphate is to be avoided, as otherwise the precipitate is redissolved to some extent. This part of the process is however not the delicate matter it might seem from the statement as will be shown later. The most satisfactory mode of proceedure is to add first say one gram of the phospate—which will not hold up the smallest traces of zinc—and if a large precipitate comes down to continue the addition. Hydrogen sulphide should give no trace of precipitate in the filtrate. It is highly advisable to work only with ammonium salts from the beginning, sodium salts being less good, and potassium salts entirely prohibited as they are carried down with the precipitate by occlusion in astonishing amounts.

The ammonium phosphate is added to the warm solution of the zinc, which is then further warmed until the precipitate is entirely free from any flocks and the solution has completely cleared. Filtering on a Gooch crucible, washing with water and then alcohol, drying at 100 C. and weighing as zinc ammonium phosphate is recommended. Using an ordinary filter paper and igniting seems to cause an unavoidable loss through reduction, no matter what care be exercised in separating the filter. It may, however, be ignited with perfect safety on a Gooch, even though a disk of paper be used as the filtering medium. In the latter case the paper should be turned above the precipitate toward the mouth of the crucible.

The details of the method, with sodium phosphate as precipitant, appear in the last edition of "Crooke's Select Methods". The original author's statement that the ignition gives low results owing to the volatility of the zinc pyro-phosphate cannot be admitted, in fact our excellent results obtained by ignition on a Gooch prove that such is not the case. The same applies to his claim that the precipitation takes place in an acid solution.

Though a difference of opinion as to what constitutes an acid solution may in some cases exist, it certainly does not seem reasonable to apply the term to a liquid smelling strongly of ammonia. The reactions occurring are probably expressed by the equations.

a. $ZnCl2 + Am2HPO4 = ZnHPO4 + 2AmCl.$

b. $ZnHPO4 + Am2HPO4 = ZnAmPO4 + AmH2PO4.$

It is even likely that these two stages are entirely separate since in a cold solution the precipitate is at first as flocculent as an alumina precipitate, while on warming it becomes as dense as barium sulphate. If only the amount of ammonium phosphate called for by the first equation is added, the precipitate remains flocculent despite continued heating.

The double equation requires nearly five parts ammonium phoshate for one part zinc and we have successfully thrown down 0.2 grams zinc with one gram of the phosphate obtaining it all as the ammonium salt. The same quantity was also perfectly precipitated with five grams of ammonium phosphate but eight grams left a little zinc in solution. Similarly 0.008 grams were completely thrown down with 0.05 and 3.0 grams respectively while five grams caused some resolution.

Returning to the question of acidity, it will be seen from the equation that mono-ammonium phosphate remains as a product of the reaction but the excess of the di-ammonium phosphate, always used in practice, decomposes on heating to mono-ammonium phosphate and free ammonia, thus determining the alkalinity of the liquid. The precipitate is soluble with great facility in any kind of acid or in excess of ammonia. Too much cannot be said in favor of the process for accurate work.

Copper is determined in smaller quantities by the iodide method and in larger quantities by the new process described below. The latest literature added to the iodide method is Low's paper, J. A. C. S. 18. 458. He introduces two modifications: Oxidation of any arsenic present with potassium chlorate and neutralization of the excess of nitric acid with zinc acetate.

There is no doubt, as Low states, that the end point is better as a result of the use of zinc acetate than when the sodium salt is employed; the oxidation with chlorate is also a great step in advance for the process. It is however a mistake to use any acetate as the end point is then at best not clear—though with practice it can be distinguished.

Some time ago the writer had the honor to present to this Section a paper on the iodide method for copper, in which it was proposed to avoid the inaccuracy introduced by the presence of arsenic by separating the copper from it with glucose in the well-known manner. The object was to retain the clear end point when the titration is conducted in a very slightly sulphuric acid solution. Since that time the following relative to the subject has been ascertained :

When copper and arsenic, either as metals or sulphides, as obtained in the course of analysis, are dissolved in nitric acid, there is very apt to result a solution of the arsenic both as arsenic and arsenious acid. If now this solution be boiled with chlorate in a fairly concentrated condition, all the arsenic is oxidized to the higher form. Arsenic acid in strongly mineral acid solution, mixed with an iodide, is reduced to arsenious acid with liberation of iodine, causing the result for copper to appear high. In a solution which is however only faintly mineral acid this reaction does not take place, in fact free iodine will then even oxidize arsenious acid to some extent but far less so than in acetic solution. In the presence of little acid and arsenious acid the result for copper would therefore appear low since the iodine liberated by the copper would be in part consumed by the arsenic instead of being measured by the titrating liquid. If the copper solution be only faintly acid and the arsenic all present as arsenic acid, an accurate result for copper is obtained in sulphuric acid solution and the end point with starch is vastly superior than if either zinc or sodium acetate have been used. The thiosulphate solution should be standardized on approximately the amount of

copper found in the assay—conveniently obtained by measuring out a standard copper sulphate solution—if the best results are to be gotten, in the writer's experience a little more than the theoretical amount of iodine being liberated, and this not in absoultely uniform ratio. For small amounts of copper it is advisable to allow the solution to stand a given time—say ten minutes—between the addition of the iodide and the titration, otherwise the end point will come and go in a rather unsatisfactory manner.

While the method is good—very much to be preferred to the cyanide titration of Parks and Mohr—after an extended experience with it we must certainly dissent from Low's claim of superiority for it as against the electrolytic assay.

NEW PROCESS FOR COPPER.

This depends on the precipitation of the copper as cuprous thiocyanate according to Rivot, and the alkalimetric determination of the combined thiocyanic acid.

The solution is evaporated with as little sulphuric acid as possible to expel any volatile acids; warm gently after dilution and add sulphurous acid until its presence is plainly apparent by odor. Precipitate with an alkali thiocyanate. When the liquid settles perfectly clear, which is promoted by further warming, filter and wash well with water.

Transfer the filter and contents back to the beaker in which the precipitation was effected, boil with a measured excess of standard caustic alkali, a few minutes is sufficient, then cool and dilute to a convenient bulk (200 c.c.) Aliquot one-half after passing through a dry filter and titrate to neutrality with standard acid and methyl orange.

The rationale of the process is that caustic alkali converts cuprous thiocyanate into cuprous hydrate and alkali thiocyanate, the latter body being neutral to methyl orange. The reaction proceeds quantitatively according to the equation

$$2CuSCy + 2NaOH = Cu2(OH)2 + 2NaSCy.$$

with all quantities of copper, one equivalent of caustic soda

equaling one of copper. Not requiring an empirical standard being one of the advantages of the process. The writer claims for it greater accuracy than the iodide method is capable of.

Antimony is determined by Mohr's method—titration with iodine in alkaline solution, antimonic acid being previously reduced by the methods of Gooch and Gruener, A. J. S.42. 233. This is very much to be preferred to the oxidimetric method again recently advocated by Thompson, J. S. C. I.15. 255, or to any attempt at separation from tin.

Lead is determined as sulphate, filtering on a Gooch with paper disk, drying and weighing. In this manner the determination is capable of great accuracy, the drying being much better than ignition.

Tin is weighed as oxide or in presence of antimony is determined by difference in weight.

Arsenic by Lundin's distillation process as described by Blair in his work on iron analysis.

Phosphorous as magnesium pyrophosphate.

GENERAL CONSIDERATIONS.

When an alloy is treated with nitric acid a more or less white residue remains insoluble. This contains all the tin, part of the antimony, iron, arsenic, phosphorous, copper and lead, the two last, of course only in small amount, though the copper may amount to several milligrams. No manner of treatment has been found to obtain this residue free from iron and copper. If all excess of nitric acid be evaporated and the residue again taken up with dilute nitric it is possible to retain all the iron in the residue provided the tin is present in fair amount. The same applies also to the arsenic and antimony, though it is probably unsafe to count on this. In no event can the insoluble residue from a brass or bronze be considered sufficiently pure to weigh as stannic oxide. We separate the iron, copper and lead from the tin and antimony by fusing with sodium thiosulphate and dissolving in water, preferring

this to attempting to make the usual alkali sulphide separation in solution with all the copper and lead. The thiosulphate is a neater and quicker flux than carbonate of soda and sulphur.

If to save time in determining tin alone, when phosphorous, arsenic and antimony are absent, it is desired to obtain the weight of stannic oxide by difference, the nitric acid insoluble residue may be ignited and weighed, fused with thiosulphate, dissolved in water and the sulphides of lead, copper and iron remaining removed by filtration. The filter is then moistened with nitric acid and ignited in the same crucible—the fusion does not alter its weight perceptibly—subtracting the weight so found from the total weight of the residue. The difference is taken as stannic oxide.

A slight error must however be noted here; any lead present was weighed first as oxide and afterward subtracted partly or wholly as sulphate. It may be present to an extent that will make this error serious. If on the other hand the sulphides are not moistened with nitric acid the iron is very likely to burn only to the magnetic oxide, where it was at first weighed as the peroxide, while the condition of the lead is indefinite.

In the case of a complete analysis of an alloy containing zinc it is a great help to get the iron out of the way at this early stage, and as the copper and iron must be returned to the main solution it will be more troublesome to separate these after igniting the sulphide precipitate than to precipitate the tin directly as sulphide from the solution of the fusion, and converting to oxide for weighing. The latter also has the advantage that it is applicable in the presence of phosphorus.

Hempel, Ber. d. Chem. Ges. 22. 2478, referring to the separation of phosphorus from tin, states that some of the phosphorus invariably comes down with the hydrogen sulphide precipitate of the tin. Whether or not the same applies to the sulphide precipitate obtained as a result of acidulating the dissolved fusion we have not ascertained, but it seems probable

that it would not. At any rate the amount is too small to practically affect a tin determination in phosphor bronze. Arsenic however will largely remain with the ignited tin precipitate unless previously separated.

When the nitric acid filtrate from the insoluble residue is evaporated with a little sulphuric acid to take out the lead, there results a further precipitation of antimony. The lead sulphate cannot be removed by solution in ammonium acetate as the antimonic acid is likewise affected. A large excess of sulphuric acid prevents this second precipitation, but its presence is undesirable for the separation of copper as thiocyanate. A little tartaric acid added to the diluting water will also prevent it, and has, moreover, no effect on the copper precipitate, but this may cause the resolution of a trace of lead. For ordinary purposes this amount is negligible, but any rate it may be very easily recovered and added at a later stage.

Alloys containing antimony are usually poor in copper and free from zinc ; exceptions, however, must be allowed for and in the presence of both zinc and antimony the precipitation of copper as thiocyanate is not advisable as the scheme thereby becomes complicated. Instead the excess of sulphuric acid is used to prevent the precipitation, with the lead sulphate, of any antimony that remains in the nitric acid solution. In the filtrate from the lead sulphate the antimony and copper are thrown down together as sulphides and separated with caustic soda. In the residue the coppper may, of course, be determined by the thiocyanate process, but as it is free from any other metals it is directly available for titration by the iodide method. In the filtrate from the sulphides the zinc is obtained as phosphate. It should be remembered that if great accuracy is desired in the figure for zinc, the sulphide precipitate, after removing the antimony, is to be dissolved and again precipitated to insure against loss of zinc.

As a result of converting the mixed sulphides of tin and antimony into oxides for weighing, a slight error is sustained

owing to the fact that the two sulphides require different treatment to give accurate results. By treatment with fuming nitric acid combined sulphur is oxidized completely and the full heat of a good Bunsen burner will convert all pentoxide of antimony to tetroxide without any trouble, but while the tin precipitate requires blasting to drive out the last traces of water, antimony will not stand this heat. If, therefore, the Bunsen flame only be used, and one-tenth per cent. be subtracted from each twenty per cent. of tin found the result is better than if the actual weight obtained is taken.

As the sulphides of tin and antimony are recovered from the dissolved fusion, they are mixed with considerable free sulphur which cannot be completely oxidized with fuming nitric acid in one evaporation. For the most careful work washing the dried sulphides with carbon disulphide is necessary, but ordinarily, careful ignition will answer. After evaporating the mass to dryness with fuming nitric and burning at a temperature just sufficient to ignite the sulphur, the residue is again moistened with fuming nitric for final ignition. This is important. The paper is of course to be consumed separately. A well rounded inverted lid is used as a cover during the action of the acid.

When the ignited oxides of tin and antimony are dissolved by fusion with caustic (or carbonated) alkali, and obtained as higher chlorides in acid solution, potassium iodide reduces only the antimonic salt. We prefer to boil down twice to about fifty c.c. to insure the expulsion of the liberated iodine. The color of the liquid we have not found a safe guide in practice except that if perceptible deepening of the yellow takes place when approaching the bulk mentioned, the liquid must be immediately diluted and the second evaporation not carried quite so far. Failure to do this will result in loss of antimony by volatilization.

The separation of copper from zinc with hydrogen sulphide in hydrchloric acid is, according to Fresenius, rarely perfect. On testing a number of copper sulphide precipitates from

solutions of brass containing 15 c.c. strong hydrochloric acid in a bulk of 200 c.c. of liquid, we have never failed to find zinc in appreciable quantity. The precipitation as thiocyanate, is on the other hand, absolutely free from this source of error; and if the volatile acids are expelled with as small a quantity of sulphuric acid as possible, the amount of copper that escapes precipitation is infinitesimal. The precipitate cannot be dried and weighed with any where near the accuracy one might be led to suppose from the single experiment quoted by Fresenius. Such a procedure is quite out of the question.

The excess of ammonium thiocyanate exerts no deleterious action on the zinc precipitation with ammonium phosphate in the filtrate and methyl orange is available as an indicator for exactly neutralizing the solution. When potassium thiocyanate is used the zinc precipitate is highly contaminated, so much so that it fuses at a low heat to a clear liquid, the results being entirely without value.

THE ANALYSIS OF BRONZE AND BRASS.

(Antimony being absent.)

Oxidize one gram with strong nitric acid and evaporate on the water bath to complete expulsion of the acid. Take up with 50 c.c. three per cent. nitric acid and filter after boiling five minutes. Ignite filter and contents together in a porcelain crucible, grind the residue with a thick glass rod, and fuse with a liberal addition of sodium thiosulphate. Leach out with a little water, digest until the liquid is clear yellow and remove the precipitated sulphides by filtration. In the absence of arsenic determine tin in the filtrate by acidulating with hydrochloric acid, filtering out the sulphide of tin and washing with ammonium acetate. Ignite at low temperature together with the filter, raising the heat gradually after all free sulphur has been consumed, and finishing with a blast to constant weight.

The mixed sulphides of lead, copper and iron recovered from the fusion are dissolved by boiling with 20 per cent.

nitric acid, from which solution the iron is thrown down by ammonium acetate. The filtrate is added to the main solution and the whole evaporated with as little sulphuric acid as possible, the lead sulphate collected on a Gooch crucible and weighed.

In the filtrate the copper is thrown down as thiocyanate and its value determined by the method described. The zinc is then obtained from the neutralized filtrate with ammonium phosphate, observing the precautions mentioned.

Phosphorous is determined in a separate portion by heating some time with aqua regia, passing hydrogen sulphide into the alkalized solution and filtering. The phosphorous is then obtained with magnesia mixture as usual. If qualitative tests have shown presence of arsenic the magnesia precipitate is dissolved in hydrochloric acid, arsenic reduced by boiling with sulphurous acid and precipitated with hydrogen sulphide. In the filtrate the phosphorous is obtained with molybdate and the yellow precipitate weighed, after collecting on a Gooch crucible with a paper disk.

Arsenic is determined in a separate portion by Lundin's method, just as described by Blair, except that we deem one evaportion to dryness with sulphuric acid sufficient.

In the tin determination, arsenic is separated from the solution of the thiosulphate fusion with magnesia mixture, the tin being then obtained in the filtrate as described.

In the analysis of brass, a more rapid but not so accurate determination of the copper and zinc may be obtained by using the iodide method for the former and the ferrocyanide method for the latter. The foregoing process is carried out to the point of obtaining the filtrate from the lead sulphate. This is mixed with about ten c.c. hydrochloric acid and the copper precipitated by boiling a few minutes with strips of sheet aluminum. For a neat manner of treating this copper, consult Low's paper already referred to.

The filtrate is ready for titration of zinc with ferrocyanide according to Stone.

ANALYSIS OF WHITE METAL.

(Antimony being present.)

Proceed as in the analysis of bronze up to the point of evaporation with sulphuric acid to remove lead but in this case use about fiften c.c. of acid instead of about two. Dilute with 85 c.c. water and filter without unnecessary delay or boiling. Dry and weigh the lead sulphate.

Copper and antimony are thrown down in the solution with hydrogen sulphide, and after boiling the filtrate free from the gas and oxidizing any fine sulphur with nitric acid, zinc is obtained as phosphate in the neutral solution.

The sulphides of copper and antimony are washed from the filter back into the beaker, boiled with a little caustic soda which is passed through the filter, and the filtrate containing the antimony is added to the solution of the thiosulphate fusion of the nitric acid insoluable residue. The remaining copper sulphide is dissolved by boiling it in 1.20 sp. gr. nitric acid when it is neutralized and the copper determined with potassium iodide and thiosulphate.

The alkaline solution containing now all the tin and antimony, is acidulated with hydrochloric acid and the mixed sulphides filtered out. Ammonium acetate is used for washing as before, but the paper is separated from the dried precipitate and burned alone, followed by the precipitate itself. Ignite in the manner already described for antimony and tin sulphides in the presence of free sulphur. Having obtained the weight of the mixed oxides, it now remains only to determine the antimony, which is attained quite accurately as follows :

Grind the residue in the crucible and pour the powder into silver crucible containing about six grams of previously fused caustic potash. Re-weigh the porcelain crucible to ascertain the amount of the residue actually taken for antimony, of course, making correction for the difference later.

When fused, dissolve in water, add five grams tartaric acid and dilute hydrochloric acid to neutrality. Wash into

flask and add five c.c. strong sulphuric acid and 1.5 grams potassium iodide, keeping the solution down to as nearly a bulk of 100 c.c. as possible. Boil down rapidly to about 50 c.c., observing the precautions already referred to, dilute with boiling water to about 100 c.c. and boil down again to about 50 cc. The antimony is now all reduced.

Cool, add a pinch of dry phenolphthalein and caustic soda to alkalinity. Discharge the red color with dilute hydrochloric acid, cool again, add starch paste and 50 c.c. saturated sodium bicarbonate and titrate with decinormal iodine solution to appearance of the blue color. We find that by working in this manner one c.c. of the iodine is equivalent to 0.00615 grams antimony. Theory requires 0.0060.

The tin is obtained by the difference in weight, calculating the antimony to Sb_2O_4. From every 20 per cent. tin so obtained, subtract 0.1 per cent. as explained previously.

In conclusion, we may add that any scheme which ignores the antimony passing into the nitric acid solution when the alloy is oxidized, is not worth considering. Working on one gram it amounts to from 3 to 4 per cent. of antimony, calculated on the alloy. Some results point to the feasibility of making correction for this solubility instead of holding back the main precipitate for it.

The Duquesne Chemical Laboratory,
Pittsburg, Pa.

SECOND REPORT OF COMMITTEE ON ROADS.

There are near two millions of miles of roads in this country. The road tax is annually near fifty millions of dollars; the mud tax three hundred millions of dollars.

Pennsylvania has near one hundred thousand miles of roads, of which near two thousand miles are in Allegheny county.

The keeping of the main roads as was their building is beyond the ordinary capability of a locality. Such were built by the government as military roads (1800–1810) and State roads earlier and later, or by corporations as toll roads (turnpikes) 1810–1820, and helped to make towns especially, as still more did the canals about 1830 and the railroads (1840–1890), and now we have a suburban rapid transit road for passengers in and about every town, helping it to spread.

The maintenance of the roadways originally made as main thoroughfares for passengers and freight over long distances is now thrown on the local population, and the other means of transportation as far as they touch the wagon road have not often aided in maintaining it intact, nor contributed beyond the limits of their own right of way in its aid, though it was tributary to their business. Too often have the railroads treated the wagon road, their neighbor, shabbily; but there are splendid exceptions.

Amendment of and by the disproportionally large population of the cities is necessary; more people ought to live in the country, and the cities are to help make the highways that lead to them; not only to help the comfort of living outside, but also to help the bringing in of supplies for living inside.

It was by authority and enterprise under the government and corporations that highways, and later by either or jointly that canals and railroads were built to make the cities; so the long delayed work for getting better country roads will also have to be by special organization acting through select execu-

tive ability with honesty, courage, skill and patience earning the approbation of the people. We know the engineer will be called for, and having proper deliberative energy he will be entitled to choose his assistants and direct them.

The State roads laid out under special acts of Assembly were to be as nearly straight as possible, and not to be changed to make ascent or descent greater than five degrees from a horizontal line. The width is generally fifty feet and any encroachment reducing the open width is, like that onto our rivers, without authority of law.

Township roads, public and private, are by three viewers (appointed by the court of quarter sessions upon petition of taxpayers) viewing the ground and agreeing that there is occasion for a road, laid out; respect being had to the shortest distance and the best ground for a road and in such manner as to do the least injury to private property, and also as far as practicable agreeable to the desire of petitioners. Whenever practicable five degrees is the limit of gradient, the width is not to be over fifty feet; but two rods equal to thirty-three feet has been the width in this county and private roads twenty-five feet. Thirty feet and twenty feet are the respective widths elsewhere more general.

About all the turnpikes as well as the one national road and the State roads, are now under the supervision of the townships. But a change is now started. The Flinn road law of 1895 is proving to be a measure of practical politics this year in Allegheny county; fifteen miles in five old main roads are being made over at an average cost of ten thousand dollars per mile by the county, which, instead of the townships, will continue to care for the portions remade.

It does not seem to be a system that will be followed in other counties, as, in the estimation of the townships, it partakes of the extravagance of the city. If the improvement of main roads out of the city under the county commissioners be considered as permanently fixing the old locations—the work

now being done showing but slight deviation in line or grade preparatory to putting on stone—the estopping of better locations will be in this respect objectionable.

The effort seems to be, with purposed avoidance of land damages, to open 33 feet wide and on the centre line to place 14 feet wide Ligonier macadam 4 inches thick upon a foundation of common stone 8 inches thick. The common stone is either Telford or soft ground as single stones set on edge, or broken stone of about 3 inch size on hard ground. The Ligonier stone is 1½ inch size middlings with an inch or two of screenings as top dressing.

On the Washington road the 1 5-9 square yards stone per running foot cost $1.08, of which 50c is for broken stone and 58c for Ligonier stone; but another price is 35c for broken stone rising to 47c for Telford.

The maximum ruling gradient attained is 7 per 100, but there are exceptionally steeper places. The danger from washing out by rain is forefended by underdraining accumulation of water and shedding from the expected hardened surface what falls on it directly. Nothing short of paving can be kept on steep places, we think.

This amendment of the roads in Allegheny county under the county road engineer, our member, Mr. F. W. Patterson, has had to be withal a campaign of education. Instead of new highways with freedom to get lines giving favorable gradients the existing local conditions fixing the position of old main roads both as to line and grade has to be contended with and getting 9, 8 and 7 per cent. grades is an improvement on 16 and 12.

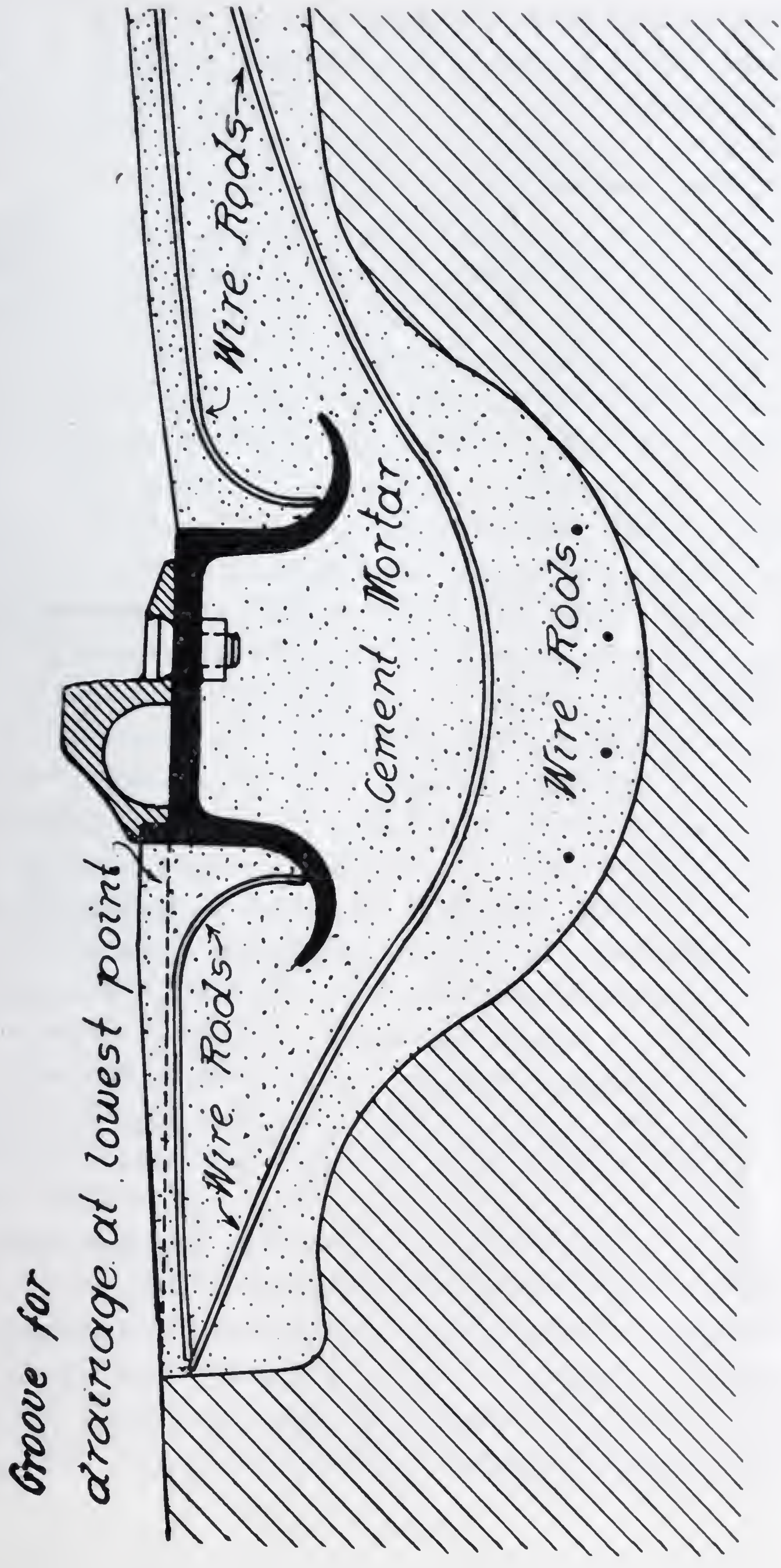
What has been attained is mostly due to the enlightened co-operation of farmers yielding to the public good and giving releases for change of location, but there are other selfish ones who would have the public incommoded to continue driving where they perhaps originally forced the road to be put against the greatest good of the greatest number.

The county engineer, our member, Mr. Charles Davis, has distinguished himself by giving us county bridges that are models for the State over. Under the old laws the roads could scarcely be influenced by him. And the two departments of unequal importance as things are, show how much has been left undone.

Three-degree highways could be had over all the terrain; that $5\frac{1}{4}$ per 100 gradient would in two miles however distributed, compass the rise from the level of the river to the level of the hilltops. In Massachusetts the maximum gradient for roads prescribed is 5 per cent., and the Alps are passed no steeper.

But cross roads and streets locally fixed must have some steeper grades. It is important and should be apparent that where the choice may be made the highway should be laid on the sunny side of the valley, and drainage away from the road bed as a prime requisite would also seem a trite remark. Whether the money now being spent here practically altogether on old roads will have the effect of preventing the present generation getting the right thing in better alignment and grade on proper location, is the question.

Perhaps the idea, often heard expressed, that the rapid transit companies are expecting to use these improved lines of roadbed will prove correct to some extent. It may be that the available taxes will about the same time give the public other improved driveways alongside by widening or alternative easier grades on nearby routes which would become the future boulevards of the extended city ; the boulevard being the wide, smooth, easy way upon which to have individual enjoyment of locomotion, or in select companionship away from the hurrying crowd, and not for freighting passengers in cars or goods in wagons, uses for profit interfering with others seeking pleasure in the going. But the county road proper should be rebuilt in one time to unite all uses of the improved highway at once, having reference to the future as well as the present ;


Groove for
drainage at lowest point
Wire Rods
Wire Rods
Cement Mortar
Wire Rods

moreover with the flat rail tramway the idea of fixedness to one paramount use is avoided and advantaged traction of every kind cheaply attained ; for the detachable car rail may be surmounted upon the flat rail to remain during a period. (See cut of Melber combined flat rail and car rail.)

In 1889 Governor Beaver deemed it important to suggest to the legislature consideration of the practicability of improving the public roads of the State, which then procured the appointment of a commission of fifteen, of which our townsman, David McCargo, was one, to collect and publish with the general road laws a list of the multitude of special road acts, and to recommend legislation. Their first report appeared in 1890, and was the compilation of the old acts. To the session of 1891 they recommended legislation, which, as they state, "while not on the highest and most scientific plan should be a long stride in advance of the present system"—"a conservative reform"—"preserving the township as a unit, believing that the people will never surrender the township, as it is the basis of our State organization." The permanent improvement of township roads was to have State aid, and an appropriation of one million dollars annually was suggested for that purpose. Some of the features are like those proposed by the former committee on roads of this Society two years earlier in the form of a Bill. But only in 1897 was a law passed containing something of all these propositions—perhaps engrafted—which is held altogether in abeyance by being made to depend for going into force upon the one million appropriation, aforesaid (a purpose not otherwise mentioned in it), that may or may not be made, and if made may be accompanied by a law repealing this dormant law of 1897, which stands nullified as patchwork.

Our former committee on roads stipulated that the engineer in locating or changing roads be governed, first, by ease of gradient ; second, by directness of alignment ; third, by least amount of damage consistent with public utility. And we

shall at once subscribe to such sensible specifications under any authority responsible for making roads of any class for the people and their posterity. As then, we should wish to class into highways, roads and lanes, the ways from the town into the country objectively laid along natural routes, as *highways*; the cross ways for local communication, as *roads*; and private ways, as *lanes*. Having described the legal requirements that have governed the laying out of existing roads, and supposing the modus of caring for them by the townships is understood, we proceed to give synopsis of the suggested improvements in laws and the laws passed since Governor Beaver's message of 1889, in chronological order.

In January, 1889, the retiring president, Mr. Dempster, asked this society why should not they make suggestions to the Legislature, and one month after, Thomas H. Johnson, chairman of the Committee on Roads therefor appointed, offered a report, and an act was presented by them to the Legislature.

This early action is emphasized in importance as furnishing ideas to others, by other measures brought forward in the next session two years later and since, and by being plagiarized to the extent of eight pages in compiling essay for the prize offered by the University of Pennsylvania. We repeat here from the Act offered, which with the interesting and valuable report is contained in full in the Society's printed transactions of the year 1889.

The committee offered: An Act to provide for the location, opening, vacation, construction and maintenance of highways, roads and bridges in the several counties of the commonwealth.

Providing for the appointment by the courts of within thirty days of four persons to constitute with the county engineer or surveyor a commission which shall classify forthwith all the county's thoroughfares not included in corporate boundary lines, and divide them into highways, roads and lanes. In every township at the spring election of 1890 three

"road directors" were to be chosen for one, two and three years, so as to make one to be elected every year and the term three years. The tax levied by them not to exceed seven and one-half mills, and to be set apart as a road fund. The township to be divided by them into road districts and the amounts determined upon to be expended with a fixed rate paid for labor, in repairs, in permanent improvements, in procuring material, tools, and machinery necessary to macadamize or otherwise improve the road. Not less than thirty per cent. of road tax collected in each year to be expended in permanent improvement. The road directors in conjunction with the county engineer, his deputy or assistant to locate and open, vacate or change the location of roads upon the petition of not less than six taxpayers of the township. In locating or changing such roads the county engineer shall be governed first, by ease of gradient; second, by directness of alignment, and, third, by least amount of damage consistent with public utility. The road directors and county engineer shall act as a board of viewers under the petition to decide, with appeal to court in case of a tie vote, and the right of appeal to a person dissatisfied with the assessment of benefits or amount of damages, but not with the necessity, so that the appeal shall not retard the opening and use of such roads.

Highways to be not less than fifty feet wide, roads not less than forty feet wide, but greater widths before established in any case shall be maintained.

The county treasurer to set aside 7½% of all taxes collected in the county for state purposes, which together with the highway tax collected, shall constitute a highway fund for permanent improvement and repair of the highways as designated, and bridges on same, to be paid out on the proper requisition of county engineer.

The county commissioners and county engineer to be the board for the improvement and repair of all highways and the bridges thereon, which board shall supervise in each year the

amount and character of work to be done on each highway. Not less than 40% of highway fund shall be expended in macadamizing or otherwise permanently improving the highways, under contract after advertising for proposals.

In counties where there is no county engineer, such shall be appointed, a civil engineer of at least ten years experience, by the court for a term of three years, and at the same salary as paid to a county commissioner., The county engineer shall make a map and profiles showing location and gradients, prepare plans, etc., make contracts relative to all work authorized by board of highways or the road directors, have supervision, direction and control of all work in connection therewith, and appoint supervisors, citizens of the township having practical knowledge of road making. Make rules and regulations, have them printed and distributed for the guidance of supervisors.

The county treasurer to pay on warrant of comptroller to bearer, the charges out of highway fund and road fund, certified by the county engineer monthly to the county commissioners for approval, on sworn detailed statements of amounts severally due.

Sec. 21, the last, reads: The county engineer shall, at the close of each fiscal year, make a detailed report to the county comptroller of all work done on highways, roads and bridges throughout the county, setting forth the number of miles of highway and of roads improved during the year and the cost thereof; the number of miles of highways and of roads previously improved and the cost of repairs thereon during the year; the number, location and length of bridges built during the year and the cost thereof; the number and aggregate lengths of all bridges previously existing and the cost of repairs made thereon during the year; the number and length of roads or highways opened, vacated or changed during the year and the cost thereof; together with a full report in detail of the condition of the roads and highways at the time of the report. And

shall send a copy of the same, together with a road map of the county, to the surveyor-general, whose duty it shall be to make a connected plan of the several counties of the commonwealth; and shall make a summary report of the whole annually.

1891—From report of commission appointed under act of the legislature in 1889, describing, they say, needed legislation that moving in a conservative way will create sentiments to produce the best results in the end.

The bill provides for three supervisors elected in each township, one every year to serve for three years, and like school directors without compensation. These supervisors are to have charge of the making and repairing of the roads, highways and bridges, the appointing of roadmasters and laborers and fixing the compensation money tax, but citizens of the township between 18 and 55 may work out their tax. Board may continue or adopt the system of selling the repairing of the roads to the lowest bidder or bidders who will give bond in double the amount.

State aid to have permanent improvement by the use of brick, stone, slag, iron, gravel, wood or other lasting material conveniently to be had. The state appropriation by separate bill, as required under the Constitution, for one million dollars annually, to be distributed to the townships on the basis of the amount of road tax collected in each township the preceding year and on condition the township shall lay aside one-fourth its tax to be added to the State money and used only in stone or other permanent improvements of certain roads designated as highways.

A suitable person to be elected county engineer, to have supervision of all the roads in the county on which State money is expended; shall be one of the jurymen in laying out new roads or vacating and changing old ones, but have no control over the other township roads or the money spent on them; nor over the moneys in building new roads on the State aid money; all the money spent to be from township treasury through the board of supervisors making the contracts.

County engineer could hold supervisors' institutes, attended also by the roadmasters, from place to place for information of progress being made in other parts of the county, etc.

Penal offence for supervisor or county engineer to be interested pecuniarily in making or repairing the roads, highway or bridges or the sale of materials used.

1893—The act of June 12, 1893:

Any one or more taxpayers may by petition to court of quarter sessions with offer of bond to extent of $500 per mile acquire the right to furnish all materials and labor necessary for making, amending and repairing the public highways and bridges of the township or road district for the ensuing fiscal year, wholly at the expense of the petitioners. They must assume to pay the officers of the township or road district: to township clerk $50, to each of the auditors $25, to attorney elected as counsel by the supervisors or road commission $50, to each supervisor or road commissioner $250. In consideration of which it shall be stipulated that the said township will not lay or collect road taxes for that year.

1895—Act of June 26, 1895 (The Flinn Road law):

The county commissioners by resolution and the approval of the grand jury and the court of quarter sessions, can improve any particular main or public road or highway or section thereof in the county, making it thereafter a county road and relieving the township authorities and officers from any care over the same. Viewers are only required where there is failure to agree upon compensation for property to be taken, injured or destroyed. "Whenever by reason of the opening, widening, straightening, or extending" any road or highway or part thereof shall thereby become useless and vacated, and the property of one owner shall intervene between the new road and the land of another having no other outlet the county commissioners shall obtain transfers thereof from one to the other, or these failing to agree with each other and the lot or piece of land be in the opinion of the commissioners

insufficient for building purposes it shall be taken and used as part of said road or highway.

An annual tax of not more than two mills upon the dollar upon all real and personal property within the county taxable for county purposes provides the fund for all purposes under this act. Viewers may recommend that buildings and improvements passed through shall be permitted to remain for such time as deemed wise and proper. But in case of destruction, vacation or abandonment within that time owners shall not have the right to re-erect buildings and improvements within the line of such county road or highway.

1897—No. 160:

"An act providing for the election and appointment of road supervisors in the several townships of this Commonwealth, defining their duties, authorizing them to make, repair and maintain roads and bridges, let contracts for the same, levy and collect taxes, employ labor, divide townships into districts, appoint roadmasters and treasurer, purchase road-making implements and machines, prescribing penalties for violation of this act, and requiring the road supervisors to report to township auditors and to the Secretary of Agriculture from time to time, and for the repeal of all laws, general, local, or special inconsistent herewith or supplied hereby."

The elections in all the townships of the Commonwealth in February, 1898, are to be for three supervisors (unless there are three already in office) to serve respectively one, two and three years, so that annually thereafter the election shall be of one supervisor to serve for three years. The board of supervisors organizes first Monday in every March and appoints an outsider as Treasurer and proceeds immediately to levy a road tax which shall not exceed ten mills on each dollar of valuation as furnished by the county commissioners.

Provided that a greater rate than ten mills and not to exceed ten additional mills may be levied by order of the court of quarter sessions on unanimous petition of the board, and

every taxable shall be assessed one dollar poll tax in addition to the millage on valuation.

"A certain proportion not less than one-fourth and not to exceed one-half of the road tax levied shall be paid by the person in money, and the balance may be paid in work on the roads."

There is to be a roadmaster appointed by the board for working himself and directing the work on every five miles of road. The board may let by contract after bidding, the making and improvement of roads and bridges. Such contracts are limited to three years.

No public road hereafter to be laid out shall be fixed at a higher grade than three degrees except where it shall be deemed impracticable to open and maintain the same at a lower grade.

The Secretary of Agriculture is to have a report in March of the money raised, and a report at the end of the year (by January) of the classified expenditures.

But, says section 21: The provisions of this Act shall not go into effect until the sum of one million dollars has been appropriated by Act of Assembly, or shall have been received in the State treasury from taxes for road purposes, the same to be distributed under direction of the department of agriculture among the several townships of the State in proportion to the number of miles of public roads in each township.

Provided no township shall receive more of the aforesaid State money than is raised therein by local taxation including work and money tax, and that the money so appropriated shall be expended in making and maintaining public roads.

And section 22, the last, says:

All acts or parts of acts general special or local, inconsistent herewith or supplied hereby, to be and the same are hereby repealed: Provided, however, that the act entitled "An act enabling the taxpayers of township and road districts to contract for making at their own expense the roads and pay-

ing salaries of township or road district officers, and thereby preventing the levy and collection of road taxes therein," approved June 12, 1893; and the act entitled "An act to provide for the permanent improvement of certain public roads or highways in the several counties of this commonwealth, making such improved roads and highway county roads, authorizing the relocation, opening, straightening, widening, extension and alteration of the same, and the vacation of so much of any road as may therefor become unnecessary; authorizing the taking of property for such improvement and providing the compensation therefor and the damages resulting from such taking; providing for the payment of the costs and expenses incurred in such improvement, and in thereafter repairing and maintaining said road, and authorizing the levy of a tax to provide a fund for said purposes," approved June 26, 1895, shall not be repealed hereby, but shall continue in full force and effect. Approved June 23, 1897.

Engineers' Society of Western Pennsylvania.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Society, 410 Penn avenue, Pittsburg, Pa., Tuesday evening, November 16th, 1897, the president, Mr. Emil Swensson, being in the Chair. The meeting was called to order at 8:25, forty members and visitors being present.

The next business was the election of new members, Messrs. White and Beutner being appointed tellers. The following applicants were unanimously elected: Mr. William E. Corey, Mr. Vernon R. Covell, Mr. Alva C. Dinkey, Mr. Abe S. Isaacs, Mr. Brabazon Rutherford and Mr. Paul S. Whitman.

COMMITTEE ON ROADS.

After some little discussion, as to whether or not the printed report which appeared in the September number as the first report of the committee on roads should be read before the Society, it was finally decided that the Secretary should read a synopsis only.

Mr. Schellenberg, on behalf of the committee on roads, read a supplementary report of the committee, and at its conclusion said that the subject was an important one, and so much was yet to be accomplished by the committee, that he would ask the Society to increase the committee by the addition of three members. He suggested that one should be the county engineer, the second the county road engineer, and the third a railroad man.

On motion of Mr. Camp the addition was authorized. The Chair appointed Messrs. Charles Davis, F. W. Patterson and G. L. Peck.

On motion of Mr. Camp that the chairman appoint the usual committee for nominating officers for the Society for the ensuing year, the following gentlemen were appointed: Messrs. Thomas H. Johnston, Thomas B. Roberts and Charles Davis.

On motion of Mr. Lewis, the reception committee was instructed to make the arrangements for the annual dinner of the Society, with full power to act.

The attention of the reception committee was called to the fact that the American Society of Civil Engineers, and the engineering societies of other cities, had extended special invitations in the past to the president of this Society, to become their guest at various dinners and like occasions. The committee was further instructed to consider the advisibility of extending such invitations to the presidents of other societies to the next annual dinner.

After the reading of the synopsis of the first report of the committee on roads by the secretary, Mr. Schellenberg offered an additional report which was entitled the Second Report of the Committee on Roads. He explained that the first report grew out of the examination of Mr. Kirk's exhibit of foreign street paving blocks at the Pittsburg Exposition, and that the second report contained matter pertaining more particularly to the discussion of the subject, being the propositions that have been brought to the attention of the State Legislature at various times, with synopsis of the laws passed since 1889, thus bringing the present status of road improvement here in Pennsylvania into full view.

Mr. Schellenberg was asked to read the synopsis of the Flinn Road Law over, and he pointed out how the conflict lay between township road making and the shoving of the city improvement of roads into the country around, and that the Flinn law was not likely to be of direct application throughout the state, and effect a plan of road improvement. In answer to an opinion asked, he agreed with Mr. Chess that

the aid of the non-resident taxpayer in improving the township road should not raise opposition in the country.

MR. DAVISON—As I look at this present road improvement the people in the outlying townships are very eager for these new roads that the county commissioners are proposing to build. Every farmer, I suppose, wants one of these good roads to pass by his door, but he does not turn his attention to aid the work in the proper manner. They are very reluctant to furnish new rights of way, where the roads could be bettered by changes of alignment. I don't know as I had my attention particularly called to the report of the road committee of 1889, but I was struck by the ideas advanced in that report which Mr. Schellenberg has just repeated. The first consideration was good grades; the second was directness of line consistent with the circumstances, and the third, the least possible damage to property in laying out the roads. This is the proper order in which our country roads should be improved. As a matter of fact they are being considered in the reverse order by the county commissioners. They consider the matter of damages to property the main important feature; the matter of directness of line the next in importance; and the grade does not seem to cut much of a figure. They are avoiding the splendid chance to make a record for themselves by carrying on the work in this latter way. They seem to be in too much of a hurry to please a large number of people at once, and are thus improving roads before they have had time to give the requirements proper consideration. I understand that the reason they assign for not making radical changes in the re-location of some of the roads that are being improved is that they fear that they do not have sufficient authority under the Flinn act, or any other existing act or acts. In my opinion these legal points can and should be gotten around some way.

ARTHUR KIRK—The road making now being done by our county commissioners is not much of an improvement over the

old system, because they are leaving so many steep grades on old located roads.

I have been told by Mr. Patterson that he finds himself compelled, by the surrounding circumstances, to make parts of the new roads eight, ten and twelve feet rise in a hundred feet of road.

All my experience in road making and road using causes me to say it is not desirable to have any part of the road steeper than three feet to a hundred, and all authorities on road making which I have seen agree with my experience, and condemn any grade that is more than five feet to one hundred feet, or five per cent. As a chain is only a chain in proportion to its weakest link, I say a goat path is only a road in proportion to its steepest grade; and if our county commissioners instruct their road engineer to make such steep grades, I think it a wilful waste of public money. *All expenditure in transportation is waste*, and every civil engineer, in locating roads, should bear in mind that one steep grade in a road may entail a perpetual loss on every one using that road for hundreds of years.

I remember some forty years ago when I was a resident of Butler county, twenty-four miles from Allegheny City, while helping a neighbor farmer to load his wagon for a trip to Pittsburg, he said: "I would like to take five bags more of potatoes, but I have to get up Deer Creek hill." Five bags of potatoes would be one-third of his load. It always took two days to make such a trip to market. Counting that team of horses worth $3.50 per day, and cash expenses $2.00, would make $9.00 that the farmer had to take out of the price of that load before he had any pay for use of land, and for seed, plowing, harvesting, etc., and Deer Creek hill caused him to lose $3.00 more because it was so steep a grade.

Now I am informed by a very reliable man who was born and grew to manhood in sight of that Deer Creek hill, that at least an average of twenty teams per day went up that hill

every day for fifty years. This shows that the engineer who located that road up the steep, long hill, caused a loss to the users of that hill of $900,000, and the road is still there, although the name of locating engineer is now unknown.

Besides all this, I think the Flinn law is clearly unconstitutional and no person should pay one cent of county road tax for the following reason: When William Penn got the grant of the land now called Pennsylvania from the King of England, he was anxious to have emigrants go to his possessions in America. He published a prospectus, showing what he would do. Among other things he promised to *make all roads between cities* at his own expense. But when the emigrants came here, they found this could not be carried out, because no person could tell where cities would grow up, and after some years of consultation about this, it was finally settled that when the proprietor (William Penn) sold one hundred acres of land, he would only take pay for ninety-four acres and reserve the six acres out of every hundred, with which he would make roads when needed.

A case was decided in the Supreme Court in 1837, which decided that those six acres still belonged to the State and can be taken by the State, and the State only, to make roads when needed. Hence there is no authority for the county to collect money or take land with which to make roads.

The Flinn road law leaves it optional with each county to adopt it or not. As far as I know "ring-ridden" Allegheny county is the only county that has adopted it, and I am confident no person has any authority to collect a tax under it.

With the approval of the President, a synopsis of the Flinn law was read.

Mr. Kirk—Does not the Flinn law conflict with the compromise made with William Penn?

Mr. Schellenberg—My dear sir, I am not sitting as the Supreme Court at present.

Mr. Kirk then presented a full sized sample of Liverpool street pavement to the Society. This pavement had been presented to Mr. Kirk by Mr. James Morgan, who has been twenty-three years chief engineer of the streets of Liverpool, England. This sample of street pavement had been exhibited at the last two Pittsburg Expositions, had been examined by thousands of intelligent men, and every one of them pronounced it infinitely superior to any Pittsburg pavement. This sample of Liverpool street pavement was very clearly explained and illustrated on page 378 of printed report of the September meeting of the Engineers' Society, and will be on exhibition in the rooms of the Society, No. 410 Penn Ave., Pittsburg, where any member can inspect it. It dispenses with all wood ties or ties of any kind, and the face of the rail can be removed for repair without taking up any of the pavement for repair. (In the cut on page 378 the rail support is shown divided up into chairs; but it is really continuous.)

Mr. H. J. Lewis—In my opinion, the first step in this matter should be a complete topographical survey of the county, from which a careful and comprehensive study could be made, taking into account the natural lines of present and future traffic as far as the latter may be foreseen.

Allegheny county is peculiar in its surface, and in the distribution of its traffic. Divided as it is into three great triangles by the three principal rivers, the former are isolated from each other except where connected by ferries or large and expensive bridges. The location of these bridges is, of necessity, limited by considerations of economy, and the road plan should be in harmony as a matter of course.

Pittsburg, lying at the center of this territory, both geographically and commercially, is the point to and from which all principal roads must lead. With these main valleys and their tributaries radiating naturally, almost, from the city, the problem of roads would be comparatively easy, were it not for the fact that the railroads have pre-empted all the best

locations, and in many cases control the situation so completely for a half mile or more that the construction of a road, in parallel, is not feasible from an economical standpoint.

The present system of roads, built up hill and down dale after the slipshod methods of the past, does not constitute a nucleus, around which the new system can be built, if it is to commend itself to future generations. The present system, although accidentally good here and there, must be completely disregarded if we are to have the best, as were the streets of old Paris by Haussmann in laying out his boulevards.

Main roads in the principal valleys being for the most part out of the question, we must look to the other alternative of reaching, following and descending from the ridges with easy grades and economical construction. This is the more difficult, for the reason that nearly every one of our roads must have one or both of its terminals at the lower levels of the principal valleys. For the grade line connecting these terminals with the ridge levels, we have in many cases nothing left but short, deep cut, broken valleys, which neither the railroads nor electric roads have, as yet, found it worth while to take up.

As a definite plan I would suggest, first of all, a complete topographical and contour survey of the county, and the preparation of a map containing contour lines, present roads, railroads, residences, postoffices, schools, churches, places of business, distributing supplies, mills, mines, and, in short, all natural and artificial features of the county from which the roads would derive traffic, or with which they would have to contend in construction. The main part of this work once done, would be finished for good and all. The new features could be added from time to time with but little trouble or expense, if the original survey left behind it on the ground a proper system of reference points.

From this map, a comprehensive study of road locations could be so well and so cheaply made that the survey and map

would pay for themselves in the laying out of the first system of main roads; and by its aid they could be much better adjusted to the network of subordinate roads than in any other manner. The information would then stand in a permanent form for reference and as a guide in the lay-out of all future work. Any other method must be, very largely, a grope in the dark on account of the lack of complete information, and it will be very easy to waste in construction over rough ground much more than the cost of surveys. The Penn'a R. R. has made such maps of all tributary territory.

The above is simply an amplification of the time honored maxim, "Be sure you are right and then go ahead," of which we must all admit the force.

Mr. Davison—I heartily agree with Mr. Lewis in all he says. I see by the daily papers that the county commissioners are congratulating themselves at the low cost of improving our roads, about $9,000 per mile. My advice to them is not to brag too much about that. Some day they may regret that they had not spent two or even three times as much per mile; as, in my opinion, the present plans of improvement are too much on the "make shift" order. I suspect that the improvement of their roads is being carried out, not as an engineering problem, but as a political one. It might be well to place tablets at these so-called improvements, that future generations may read who was responsible for the work done upon them.

MEETING OF THE CHEMICAL SECTION.

PITTSBURG, PA., Nov. 18th, 1897.

The regular monthly meeting of the Chemical Section was held in the lecture room of the Society's house, 410 Penn Ave., Nov. 18, 1897. Chairman, W. E. Garrigues. Attendance, 14.

The minutes of the last regular meeting were read and approved.

Mr. J. O. Handy, for the committee on literature, reported an abstract of recent papers, which were briefly discussed by those present. The chairman appointed the following committee on nominations for officers of the ensuing year: Messrs. Camp, Johnson and Phillips. The committee to report at the December meeting. The paper of the evening on "The Melting Point of Inorganic Salts" was read by Dr. Walther Riddle and discussed by Messrs. Garrigues, Phillips, Stahl and others. (Dr. Riddle's paper will be published later.)

Dr. F. C. Phillips read a paper on "Notes on the Chemical Composition of Natural Gas from Great Salt Lake."

The section adjourned at 10:30 P. M.

A. G. MCKENNA,
Secretary C. S.

NOTES ON THE CHEMICAL COMPOSITION OF NATURAL GAS FROM GREAT SALT LAKE.

BY FRANCIS C. PHILLIPS.

In the "American Manufacturer" for July 5th, 1897, it was reported that natural gas had been discovered upon the shores of Great Salt Lake, not far from Salt Lake City. The gas is produced from wells 500 to 600 feet deep, drilled into the sands and clays which compose the deposts of the lake basin. The lake beds have not been completely penetrated by these borings, and in so far as the strata indicate, the gas is of more recent origin than that which is found in Indiana, Ohio and Western Pennsylvania.

In the article mentioned the following analysis of the gas was cited: *

Carbon monoxide	1.2	per cent.
Hydrogen	16.6	" "
Methane	22.3	" "
Ethane	37.8	" "
Ethylene	0.6	" "
Carbon Dioxide	0.8	" "
Nitrogen	19.7	" "
Oxygen	0.9	" "

The composition of this gas, as shown by the published analysis, would appear to be quite different from that of the natural gas produced so abundantly throughout the territory extending from West Virginia northward to Lake Erie. In many tests of gas made at the wells, and at intervals during several years, in Western Pennsylvania, I have failed to detect even traces of free hydrogen. If proof exists of the occurrence of so high a percentage of free hydrogen in the natural gas from the deposits of the Great Salt Lake basin, it might seem possible that this difference in composition corresponds to a difference in the geological age of the natural gas of the two regions, the gas of more recent origin being accordingly rich in full hydrogen, the ancient (Devonian) gas containing none, and if a large percentage of free hydrogen could be shown to be characteristic of more recent geological age, an important criterion might be found for discriminating between natural gas emanating from deep lying rock strata and that from surface deposits.

An accurate test, to determine positively the presence or absence of free hydrogen, seemed desirable in the case of the Salt Lake natural gas. But in order that such a test should be of value it is desirable that it should be conducted at the supply main conveying the gas directly from the wells. Accordingly an apparatus was planned which could be shipped

*See also "Report upon the Production of Natural Gas in 1896" by F. H. Oliphant, 18th annual report, U. S. Geol. Survey, p, 25.

to the manager of the gas company, so that, after passage of the gas and the return of the apparatus, the completion of the test could be effected in the laboratory. I have shown in a paper published in the American Chemical Journal for 1894, p. 258, that pure dry palladium chloride may serve as a delicate reagent for free hydrogen in a gas mixture. Hydrogen in a pure state, or diluted with inert gases, when passed through a glass tube containing a small quantity of this chloride causes an immediate reduction in the cold, yielding palladium and hydrogen chloride. The reduced palladium unites with another portion of the hydrogen. Assuming a formula given by Mendeleef (Principles of Chemistry, Vol. II, p. 355) for this metallic hydride, the reaction may be expressed as follows: $2PdCl_2+5H=Pd_2H+4HCl$.

On leading the gas escaping from the tube containing palladium chloride into silver nitrate solution, the presence of hydrogen chloride is made apparent by the formation of a white precipitate. As 1 part of free hydrogen gives rise to the production of 36.4 parts of hydrogen chloride, the reaction is one of considerable delicacy. In applying this test to the Utah gas it was desirable to avoid the use of liquid reagents on account of the distant shipment of apparatus, and therefore an absorption tube capable of taking up any hydrogen chloride which might be produced during the passage of the natural gas through the palladium chloride, was prepared as follows:

Two grams of pure white sand were moistened with a solution containing 0.4 gm. silver nitrate and 0.1 gm. calcium nitrate. The mixture was then evaporated to dryness at steam heat, and exposed to the air for a sufficient length of time to cause the deliquescent calcium nitrate to become moist.

Natural gas passed through the palladium chloride tube and then through the tube prepared as described, would, if it contained free hydrogen, yield hydrogen chloride. This hydrogen chloride would be absorbed by the moist calcium

nitrate which would thus promote the production of silver chloride from the silver nitrate present in the mixture.

The tubes being enclosed in a box and protected from light, a delay due to shipment would not be prejudicial to the test. The necessary drying tubes containing phosphoric anhydride were placed in position. Gas was passed through the tubes at the station of the Salt Lake & Ogden Gas & Electric Light Company, under the care of Mr. F. W. Hayward, manager, who very kindly consented to carry on the tests.

After the passage of the gas for many hours, the apparatus was returned to the University in Allegheny.

In searching for silver chloride no indications were detected, and it appears safe to assert that free hydrogen does not occur in this gas.

In experiments with artificial mixtures of hydrogen with natural gas as supplied in Allegheny it was found by the method described that 0.25 per cent. of free hydrogen in 500 c. c. of natural gas could be readily detected. Natural gas alone produced no action.

It seems safe therefore to assert that free hydrogen does not occur in natural gas from the Great Salt Lake and that the gas of recent origin from that region does not differ from that produced from the Devonian rocks of Pennsylvania as regards the presence of free hydrogen.

ALTERNATING CURRENTS — SOME RECENT ADVANCES.

BY CHARLES F. SCOTT.

About twelve years ago the commercial introduction of the alternating current system in this country was undertaken by a then small company of this city It was met by the fierce antagonism of rival interests and the ridicule of experts. Some seven years ago the opinion of many members of the international commission, which considered the system to be adopted for the Niagara Falls power plant, was for a long time opposed to the alternating current.

But Pittsburg has become known throughout the world as an electrical center, and is identified with alternating current working; all leading companies have adopted this system; Niagara is producing alternating current in the largest dynamos ever made, and Lord Kelvin, most notable of physicists, a few years ago opposing alternating current in the international commission, now pronounces what he sees at Niagara a revelation to him, and says that what has been done has been rightly done.

It is the purpose of this paper to briefly set forth some of the characteristics of the alternating current, the scope of the field which it may cover, the recent types of apparatus and the notable features of several plants.

ELECTRICITY AND POWER TRANSMISSION.

The function of an ordinary electric system is to receive mechanical energy, derived from water power or from fuel, to transport this energy to the place where it is to be used and deliver it as light or heat, or as chemical or mechanical power.

Electrical energy is transmitted by a current under pressure. This has many close analogies to the transmitting of energy from a pump to a water motor by the flow of water through pipes. The amount of power delivered depends upon the quantity of flow and upon the intensity of the pressure.

In electrical units, 100 amperes of current at 1,000 volts pressure are equivalent to 1,000 amperes at 100 volts. If a wire of certain size will carry 100 amperes a given distance with a loss or drop in pressure of 50 volts, or 5% of 1,000 volts, then 10 such wires will be required to carry 1,000 amperes with a loss of 50 volts. But 50 volts is 50% of 100 volts; in order to make the loss the same as in the first case the cross section of the wire must be increased ten fold, so that 100 times as much copper is required for delivering power at 100 volts as is required at 1,000 volts. If the pressure be increased to 10,000 volts the size of wire required is one per cent. of that necessary for 1,000 volts, and is but one-ten-thousandth part of that demanded by a 100 volt circuit. But while 10,000 volts is very nice for transmission it is about as inconvenient to handle or to use as steam at a pressure of 10,000 pounds would be. Incandescent lighting is comfortably accommodated by a 100 volt circuit, and motors can be best constructed for pressures from 100 to 500 volts. Higher pressures involve increased cost, reduced efficiency, and render the handling of the currents dangerous.

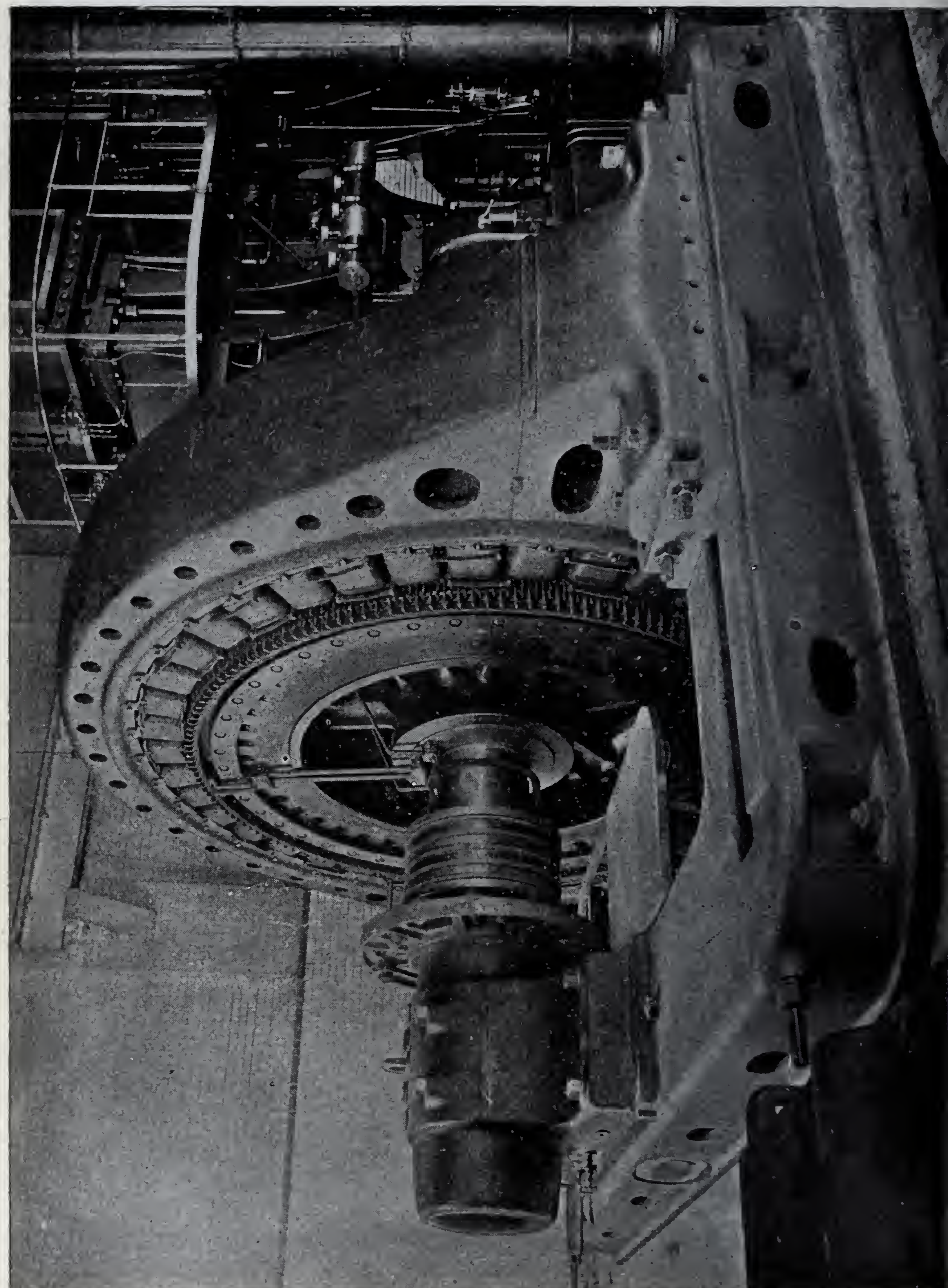
The ideal system must transmit current at high pressure and use it at low pressure; it must transmit the 10 amperes at 10,000 volts and transform it into 1,000 amperes at 100 volts.

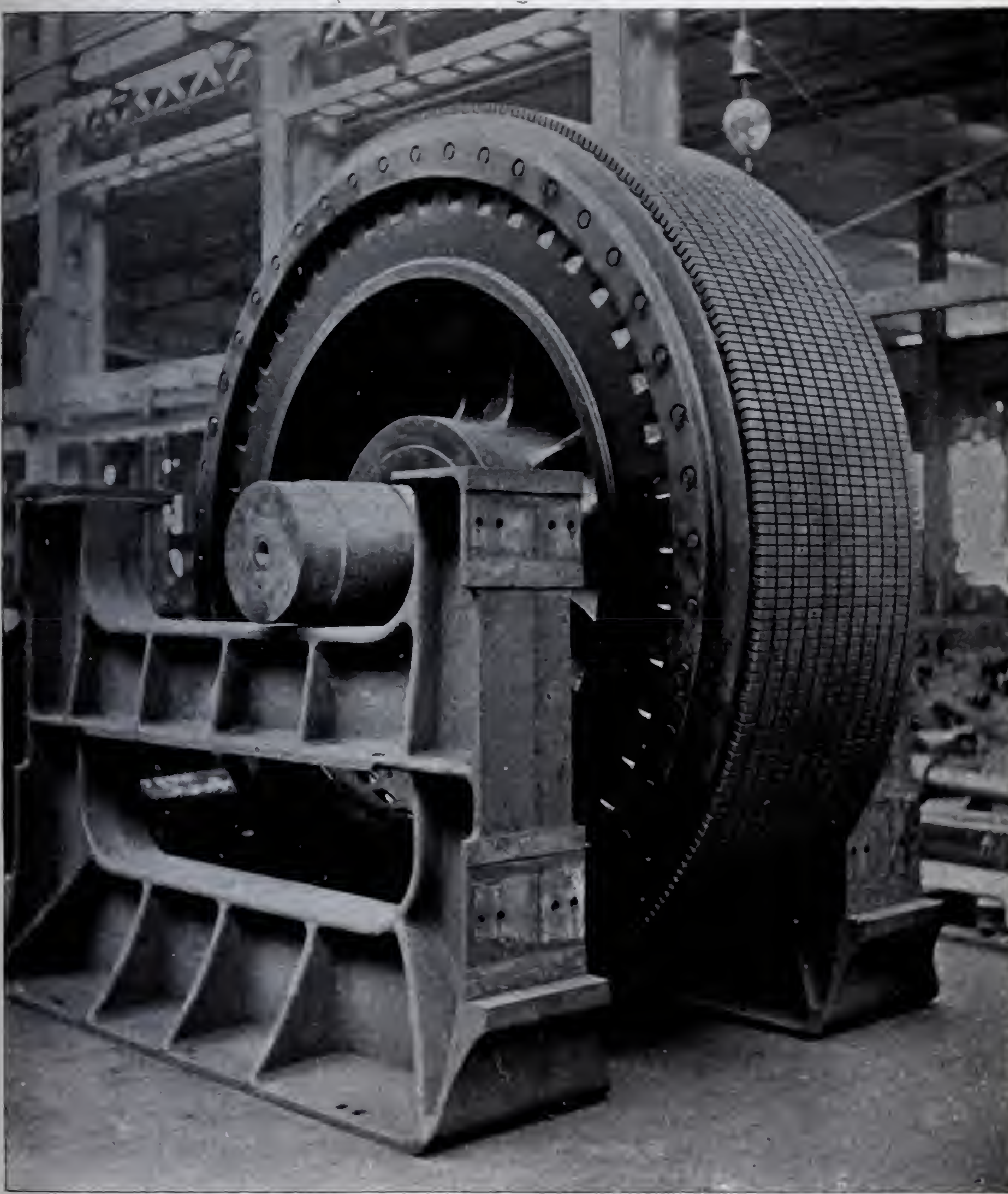
THE ALTERNATING CURRENT SYSTEM.

There is no apparatus for effectively transforming direct current from high pressure to low pressure, while the alternating current is readily and simply transformed. It is this characteristic which has given the alternating current its great commercial success.

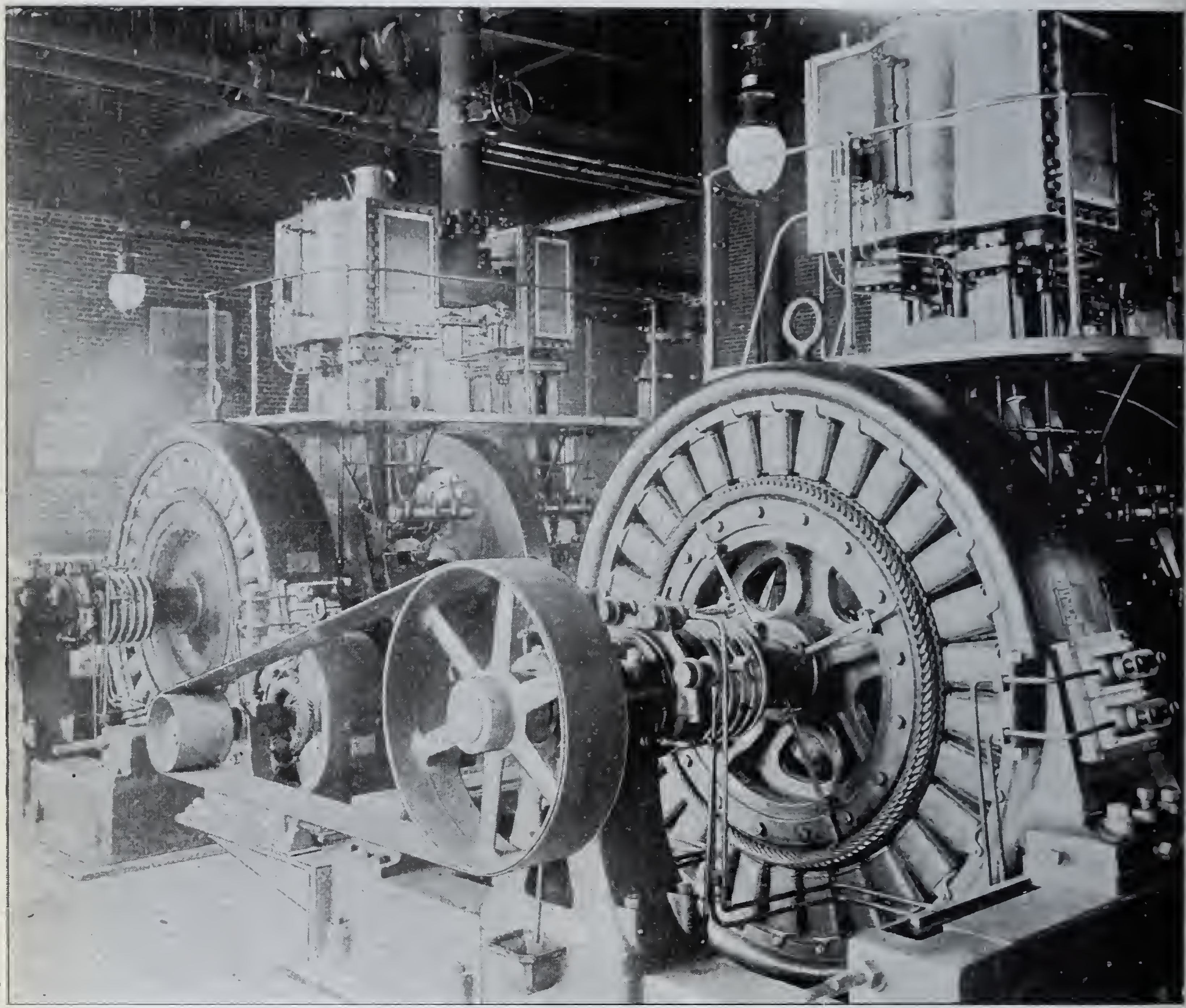
In a direct current the flow is constantly in one direction. It has a mechanical analogue in the transmission of power by a belt. An alternating current corresponds to a reciprocating motion and may be likened to motion by a connecting rod and a crank. As there are cranks of many kinds, so there is a variety of alternating currents. A shaft may be driven by a

FIELD FRAME OF 2000 H. P. ALTERNATOR. (One of four for Allegheny County Light Co.)





ARMATURE CORE FOR 1200 K. W. ALTERNATOR.



ALTERNATOR DIRECT CONNECTED TO ENGINE. (Belt drives Exciter.)

single crank, or by two or three cranks set at 90° or 120° and acting successively. In the same way an alternating current system may employ one current, or several currents acting successively, i. e., single-phase, two-phase or three-phase currents. The supply of power by a single crank or a single-phase current is necessarily intermittent, while it may be made uniform if there be two or more suitably adjusted cranks or phases.

In a number of electric plants two-phase current is generated at low pressure, transformed to a high pressure three-phase current and transmitted many miles: it is then reduced to a low pressure two-phase current. Suppose a shaft be driven by a two-cylinder engine in which the cranks are set at right angles and have but a short stroke. Strong and heavy connecting rods are required. On the same shaft may be three equally displaced cranks which are long, and therefore give a high velocity to the rods to which they are connected. The rods which are moving at the high velocity may be comparatively small and light and may therefore be extended to a considerable distance. By a similar arrangement at the other end of the rods they may drive a shaft by three cranks which is also provided with two short cranks for driving heavy rods at slow speed. In the electric system heavy wires carry two-phase current from generator to transformers, which supply a high pressure to the outgoing circuit and which are connected in such a way as to deliver three-phase current to the three wires of the transmission circuit. A reversed arrangement is employed for re-transforming to low pressure two-phase currents. This system not only combines high voltage transmission with low voltage generation and distribution, but it secures three phases with a minium number of wires and weight of copper in the long line, and also the two-phase current for distribution, which possesses a number of advantages over the three-phase current for this purpose. Often, however, the three-phase current is used throughout the system.

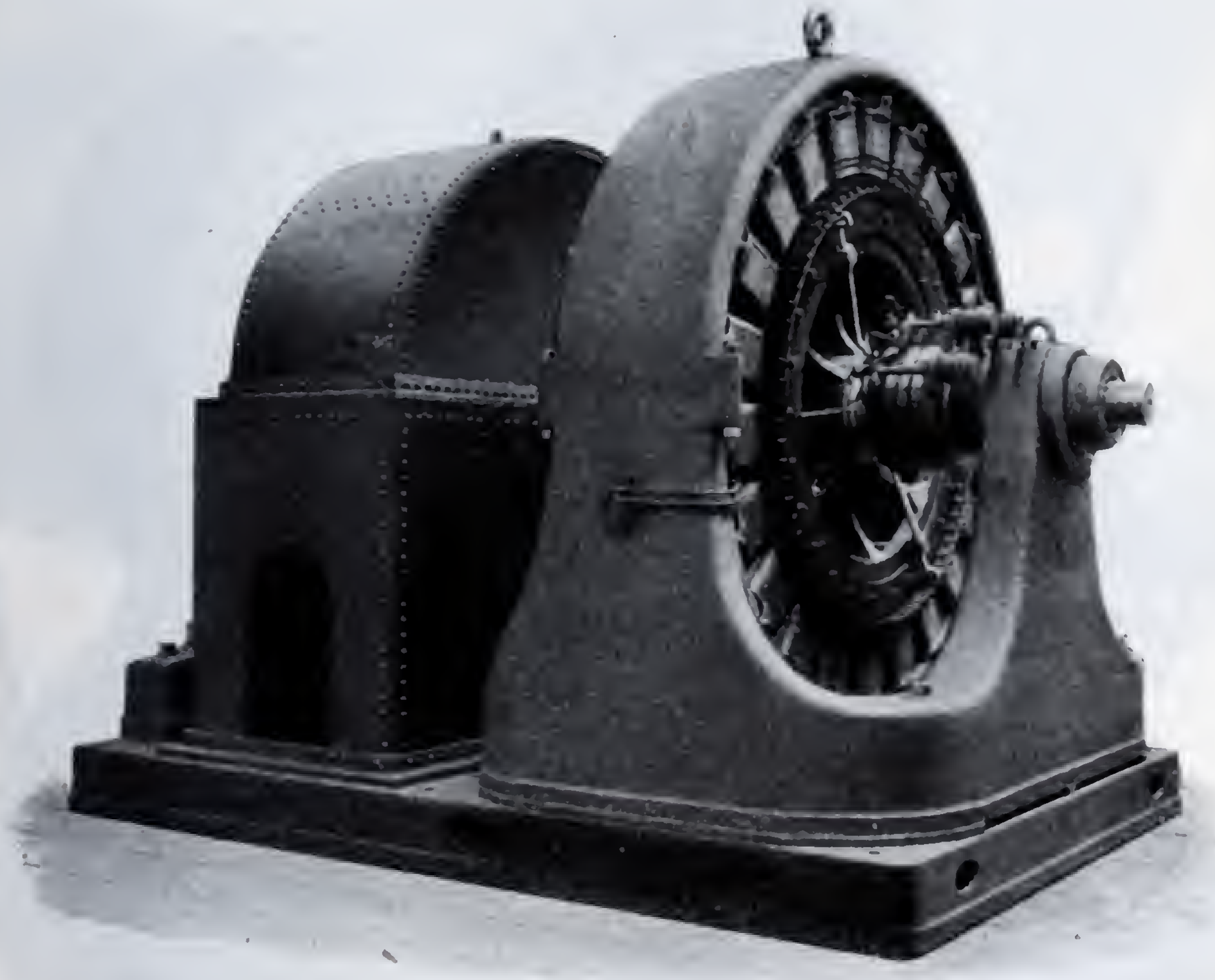
ALTERNATING CURRENT GENERATORS.

An alternating pressure, or electromotive force (e. m. f.), is produced in a wire which is moved in front of magnets of successively positive and negative polarity. Some years ago surface-wound armatures were common. The wires were wound longitudinally on the surface of a cylinder built up of discs of thin iron. This was revolved at high speed in a field having numerous poles.

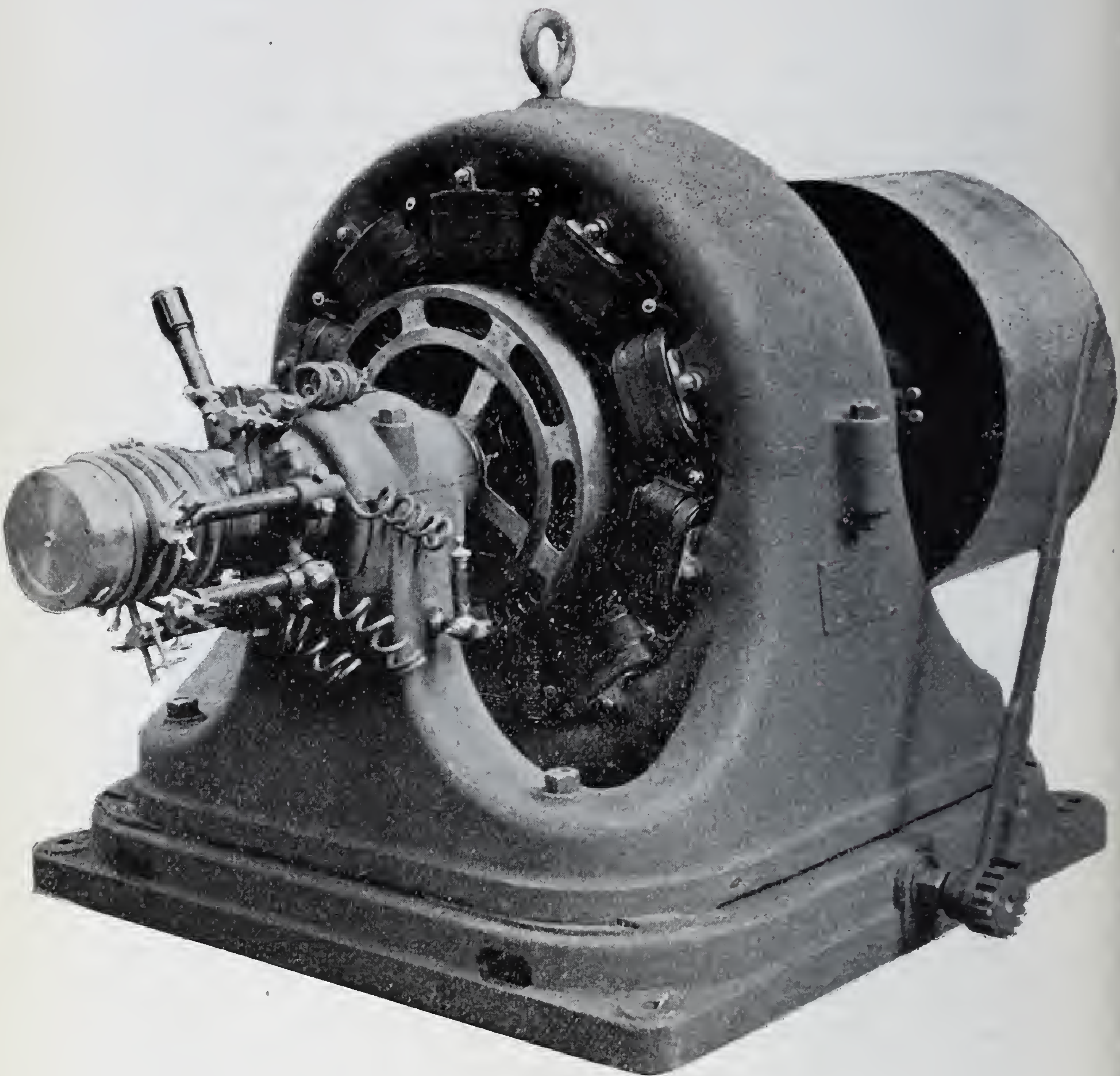
The old type of high speed surface-wound armature with its wires secured by treacherous band wires has become obsolete. Conductors are now laid in grooves or slots in the iron of the armature and are held in place by the partial closure of the slots near the top, or by wedges held firmly in the iron. In larger machines there is a single heavy bar per slot, insulated before being slipped endwise into the slot which is nearly closed at the top. The sheet iron plates are punched in small pieces, and are built up on the outside of a great central cast iron hub, to which they are held by dovetailing.

Recent engineering has been governed principally by the demand for larger units, for slower speeds, and for polyphase systems. Not long ago the largest alternator could be driven by a 250 horse power engine and its normal speed was over 1,000 revolutions. Large units are preferably direct connected to the driving power—a single shaft is often used for both engine and dynamo. This requires a very considerable reduction in speed below that which may be used when belts are employed. This has caused a reduction in frequency. The old machines produced 16,000 alternations of current per minute (the product of the number of poles and the revolutions was 16,000). If a machine is to run at 100 revolutions 160 poles would be required to give 16,000 alternations. This is beyond the limits of good design. 7,200 alternations is now common for general lighting and motor work, and about half that frequency is used in some power plants.

In the common type of generator the armature is carried

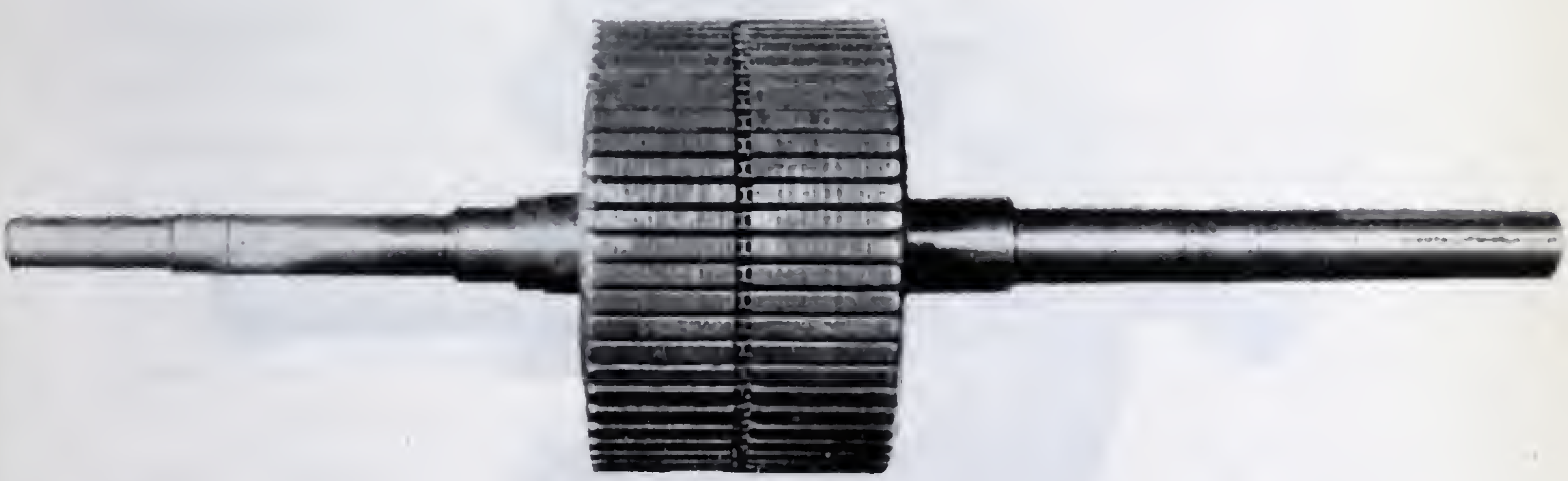


750 K. W. ALTERNATOR AND PELTON WATER WHEEL.

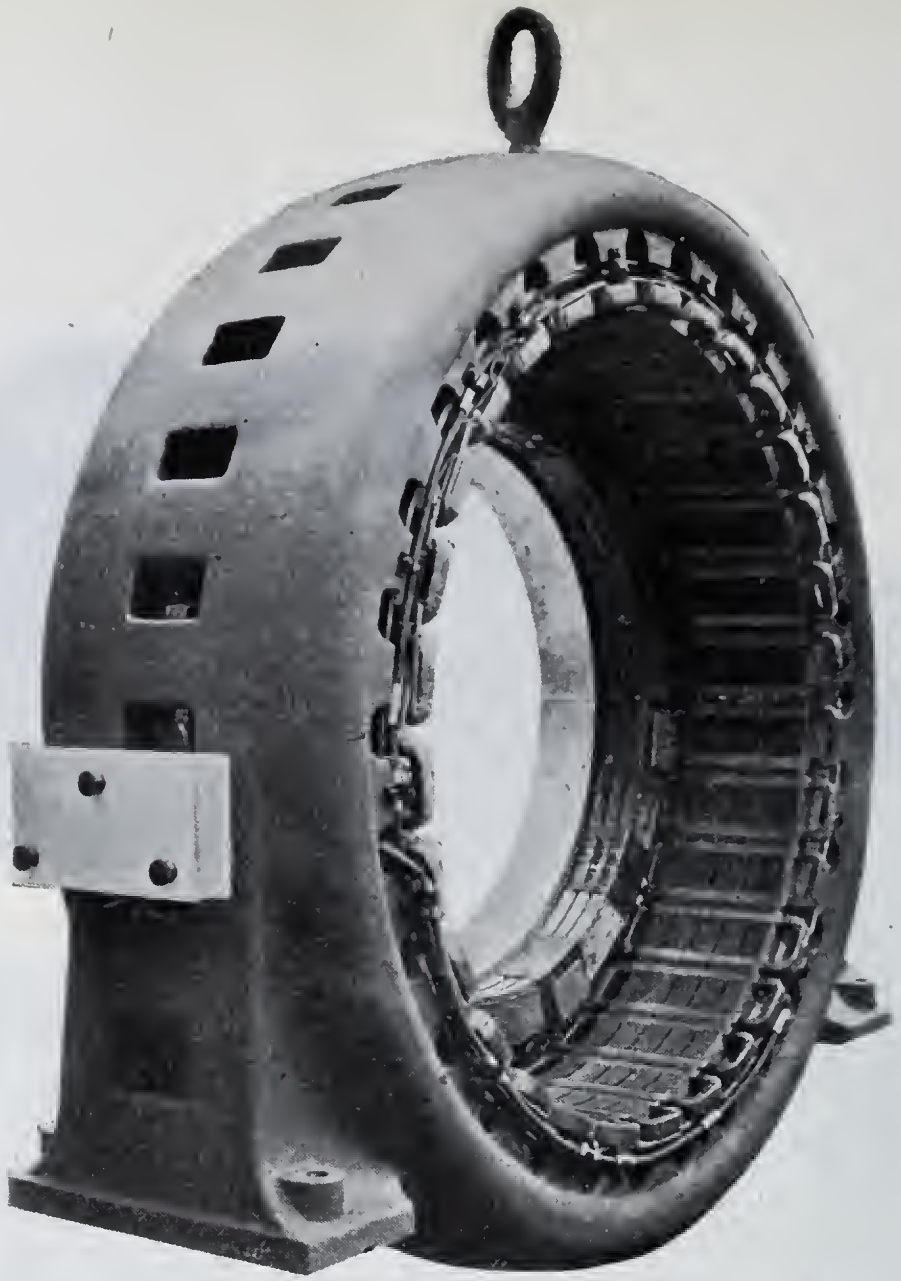


150 K. W. BELT DRIVEN ALTERNATOR.

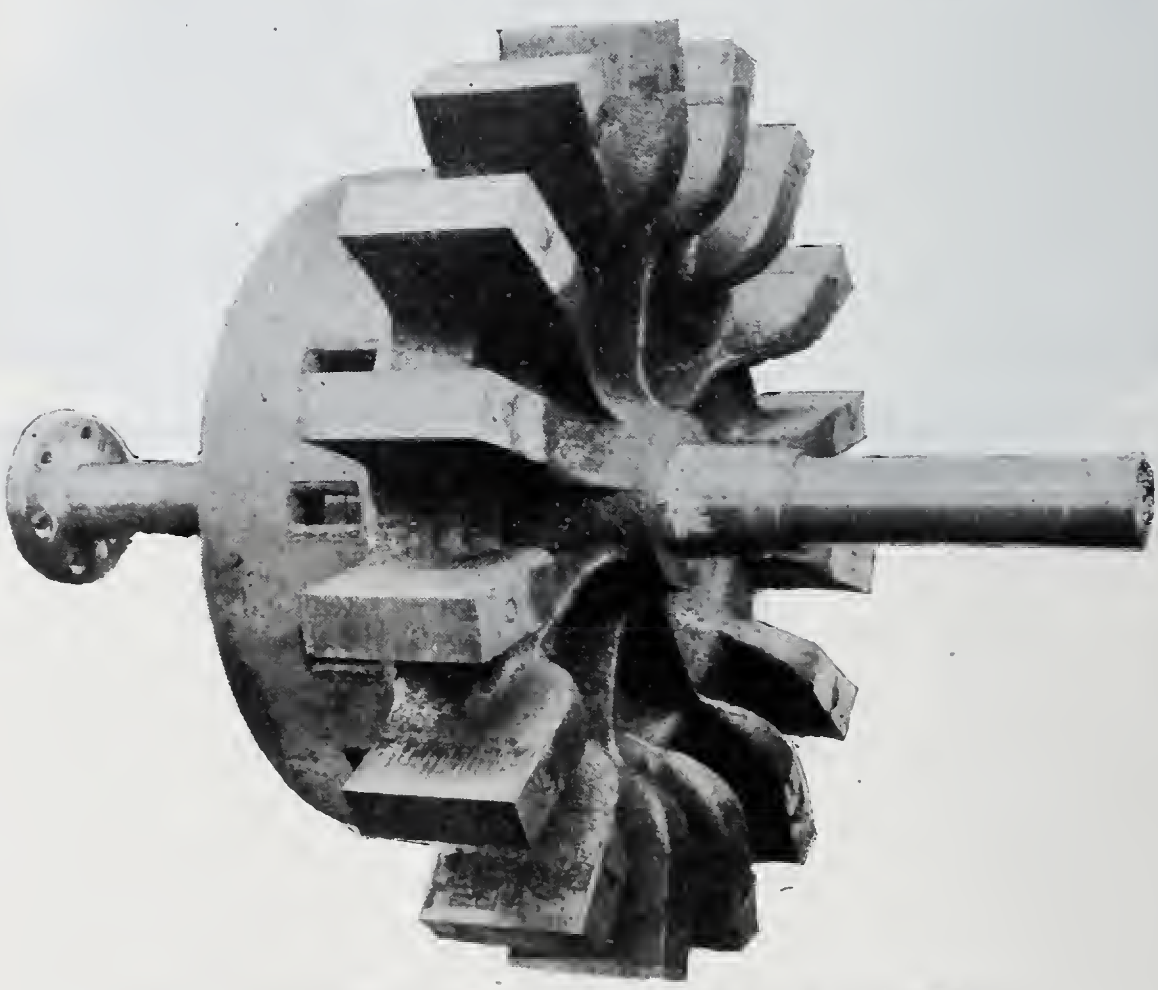
ARMATURE FOR 150 K. W. ALTERNATOR.



ARMATURE CORE FOR ALTERNATOR.



INDUCTOR TYPE GENERATOR—STATIONARY ELEMENT.



INDUCTION TYPE GENERATOR—REVOLVING ELEMENT-

on a horizontal shaft and revolves within the field casting, which is usually made in two parts, divided horizontally or vertically.

The Niagara generators differ from the ordinary dynamo in having a vertical shaft and a field which revolves around the armature instead of the armature revolving within the field. There is no electrical difference between the two arrangements

The ordinary form of machine with horizontal shaft may be turned inside out electrically, the field poles revolving and the wires in which currents are induced being placed on the inside of the surrounding cylinder. This type of revolving field machine has an advantage in having the main current in stationary conductors, which is of especial importance if the machine is wound for high voltage. There are, however, difficulties in designing and constructing machines of this type of small size.

This type of machine is employed in the generators which are being made for the St. Lawrence Construction Co. to be installed at Massena, in the northern corner of New York State. These generators are like those of Niagara in capacity, 5,000 horse power. The shafts are horizontal and carry the great revolving fields, cast iron centers, encircled by a great steel ring, to which are bolted the radially projecting poles, surrounded by the field coils. The active conductors lie in slots in the surrounding cylinder of laminated iron. The diameter of the revolving element is 15 feet, while the total diameter is about 20 feet. These machines will deliver three-phase current at 2,200 volts and 3,600 alternations per minute. Fifteen machines are to be installed. Like the Niagara generators these will be a product of Pittsburg.

Another type of modern machine is the Inductor Generator. This is a modification of the revolving field machine in which alternate poles are removed and the magnetizing current instead of passing through coils on the several poles, now passes through a single stationary coil. This machine is necessarily heavier and more costly than the ordinary type of dynamo, which usually more than compensates for the me-

chanical advantage of having no moving wire and consequently no connecting rings and brushes.

MULTIPLE RUNNING.

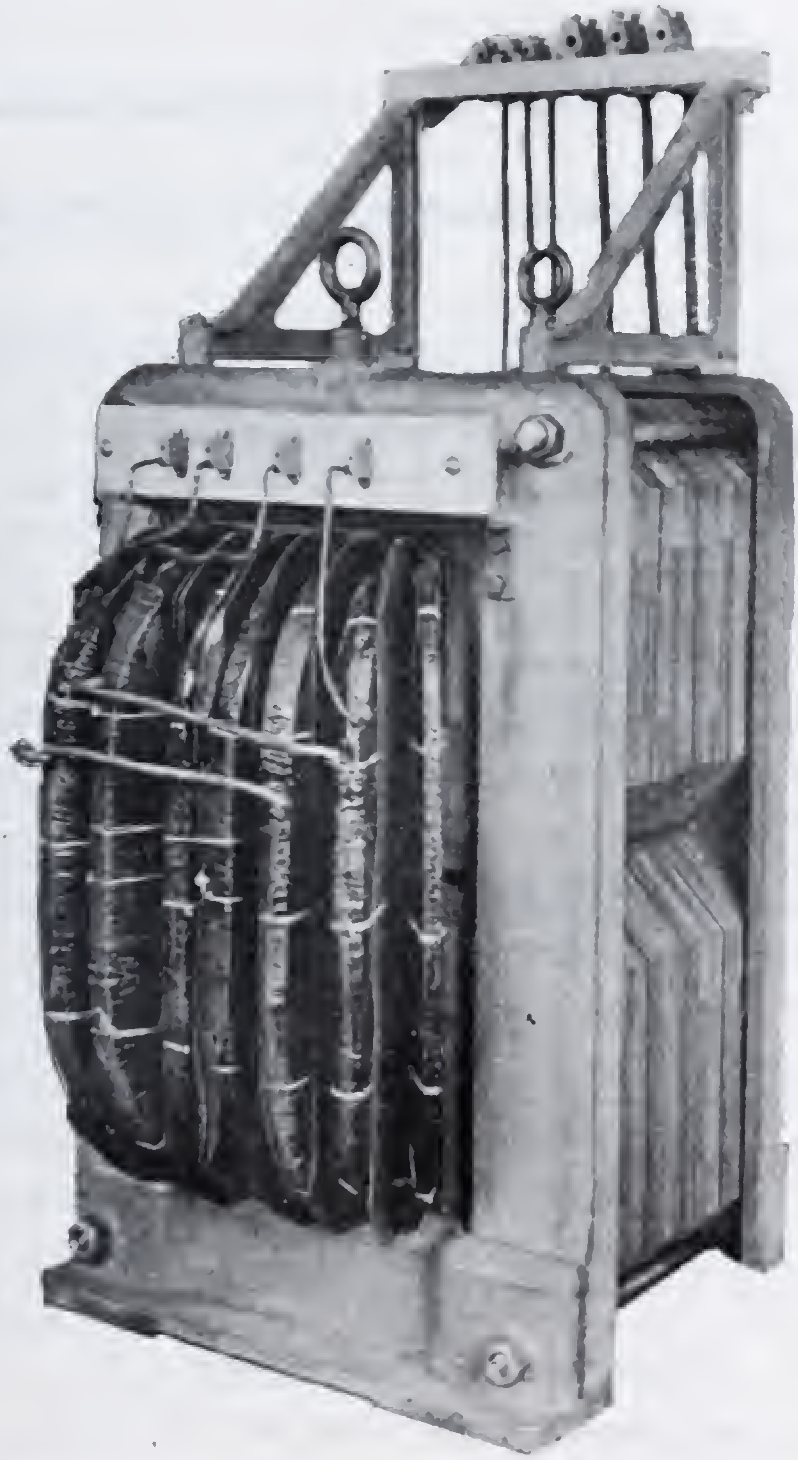
Almost all alternators now made are wound for two phases or three-phases, and multiple running is now becoming the common practice. This requires that the generators give identically the same frequency. Not only must the engines driving two similar alternators make the same number of revolutions per minute, but the speeds must be alike within close limits during each part of the revolution. Moreover, the governors must be so adjusted that each engine delivers its proper proportion of the total power when the engines are running at identical speeds.

The necessity for these requirements may be illustrated by a mechanical analogy. If engines supply power to a common shaft through gear wheels and pinions it is essential that they run at the same speed, that they maintain the same angular velocity, and that each engine deliver its proper proportion of power. The broken cogs which may result from a violation of these conditions indicates the stresses which are set up in the shaft—stresses which in the less rigid electrical system may be observed by the flow of current between the armatures. The principal problem in multiple running is therefore in the regulation of the driving power rather than in the generators.

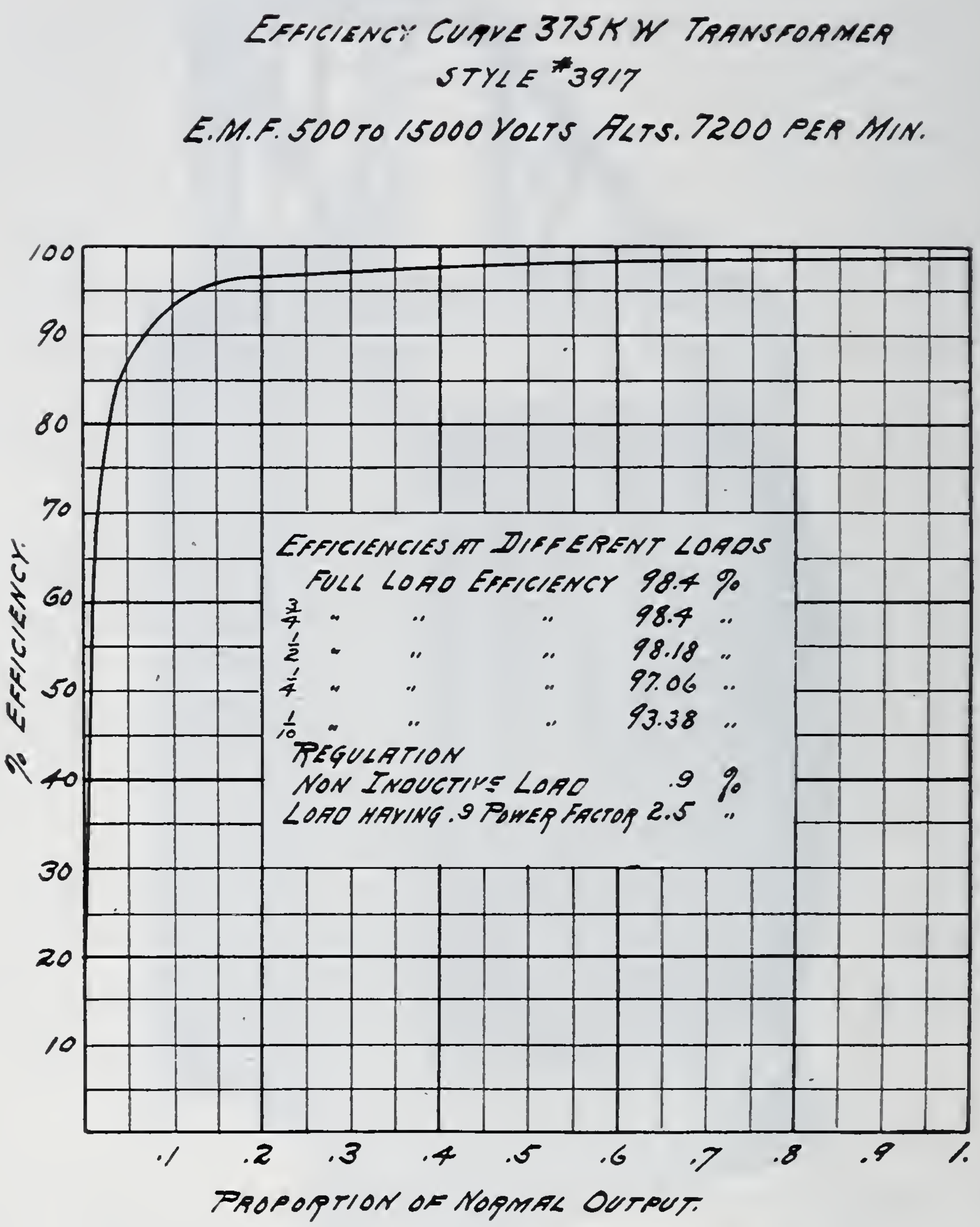
TRANSFORMERS AND TRANSMISSION LINES.

A transformer, or converter, in an electrical system, is like the lever in mechanics. It is the means of varying the ratio between quantity and intensity.

In its simplest form it consists of two coils of wire wound around an iron core. The primary coil receives current, magnetizes the iron, which induces a pressure in the secondary coil. This pressure is related to the pressure on the primary coil in the same way that the turns are related ; if there are



375 K. W. (15,000 VOLT) TRANSFORMER REMOVED FROM CASE.



NEW TRANSFORMER—EFFICIENCY CURVE.

ten times as many turns the pressure is ten times as great, and vice versa. The current, however, is in the inverse ratio, so that the product of current and pressure is the same for primary and for secondary.

Transformers for incandescent lighting are commonly made for 5 to 500 lights, or about $\frac{1}{3}$ to 30 horse power. These ordinarily reduce from 1,000 or 2,000 volts to 50 or 100 volts. Transformers for power transmission are made of all sizes up to 1,000 horse power and larger. Large transformers are usually placed in cases containing oil, which serves the double purpose of insulation and cooling. The circulation of oil carries away the heat caused by the flow of current through the coils and the reversals of magnetism in the iron. The case is provided with a large radiating surface, or coils of pipe through which water flows. A transformer may have a very high efficiency and yet require special means for removing the heat. A 1,000 horse power transformer with an efficiency of 98½% has a loss of 15 horse power in the space of about a cubic yard. To remove this amount of heat without undue rise of temperature from a compact stationary mass, containing much material which is good insulation for heat as well as for electricity, easily justifies special devices.

Both the primary and the secondary windings of large transformers are divided into several coils. This facilitates cooling and secures advantages in electrical performance.

Long distance power transmission plants employ either high voltage generators, or more commonly low voltage generators and raising transformers. In general, the cost of copper for transmission circuits is in fair proportion to that of the other elements of a plant if the voltage is between 500 and 1,000 volts per mile. The cost of copper is a large item if the voltage is 300 and 500 volts per mile, and becomes prohibitory if the voltage is much less than this.

The distance to which power may be economically transmitted is limited by the voltage which may be employed.

Pressures of 10,000 or 15,000 volts are used in many plants; 20,000 volts is soon to be used on the Niagara-Buffalo transmission, and a plant in Southern California, which is soon to be started, will employ 30,000 volts and cover a distance of over 75 miles. The critical element in such a line is the insulator for supporting the wire. The insulators must be of compact, vitreous material without flaw, or the current will pierce through the material from wire to pin, and they must be of generous size to prevent the current jumping over the surface to the pin. The highest grade of mechanical construction is demanded for insuring the durability and integrity of the line. Hard drawn bare copper wire or cable, if the cross action be very large, is used for conductors, and glass or porcelain, principally the latter, is used for insulators.

ALTERNATING CURRENT MOTORS.

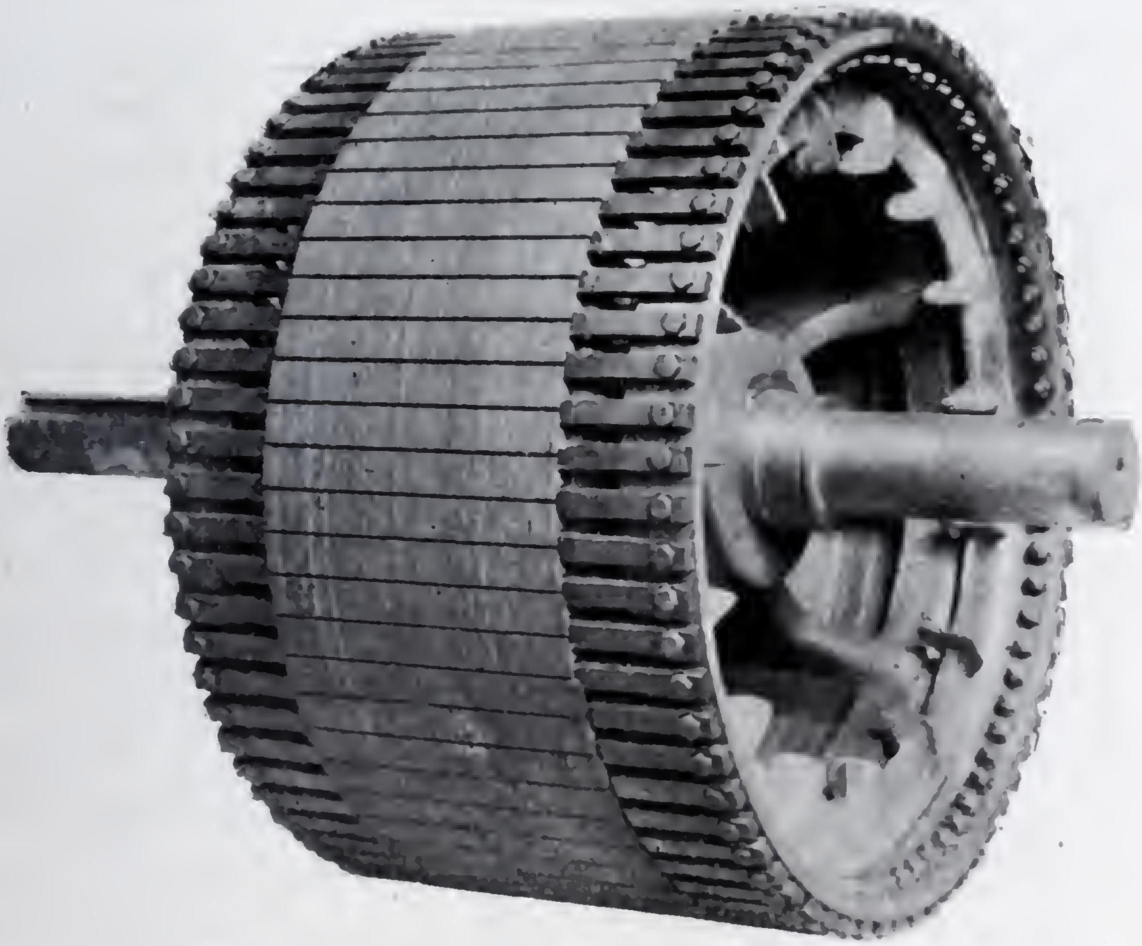
Commercial alternating current motors (with few exceptions) are made for two-phase or three-phase circuits, and are either of the synchronous or of the induction types.

A synchronous motor is similar in general construction to a generator. The same machine is often used either as motor or generator, as in the Hartford plant, which will be referred to again. The speed of a synchronous motor bears an exactly definite ratio to that of the generator which drives it. It has little torque at low speeds; it is often started by another motor and is connected to the circuit when normal speed is attained. If its maximum capacity is exceeded, it will stop. It is much better adapted for large powers than for small sizes in miscellaneous work.

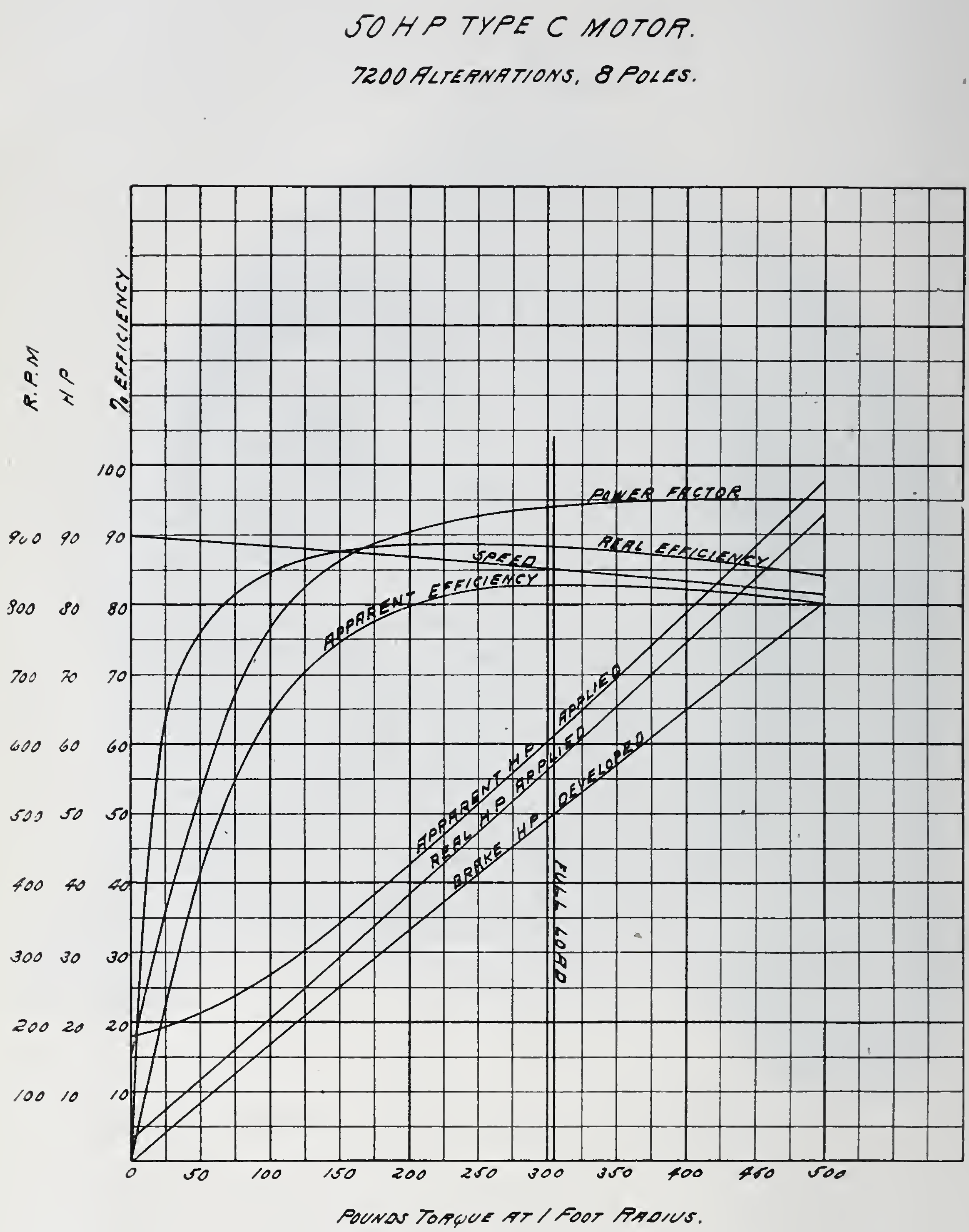
In one element of the induction motor the currents are not obtained from an external source, but are induced or generated wholly within its own windings very similar to the currents induced in the secondary of a transformer. This renders connection to other conductors unnecessary. When the induced or secondary element rotates there need be no brushes for electrical connection to the windings. Sometimes the sec-

ALTERNATING CURRENT INDUCTION MOTOR.

INDUCTION MOTOR—STATIONARY PRIMARY.



INDUCTION MOTOR—REVOLVING SECONDARY.



INDUCTION MOTOR—PERFORMANCE CURVES OF CONSTANT SPEED TYPE.

ondary element is placed outside, and the primary rotates, the currents being introduced through brushes resting on collecting rings. This sacrifices some elements of simplicity, and is a type which is practically superseded.

The induction motor tends to run at the same speed as a synchronous motor which has the same number of poles, but there is a slight falling off in speed, or slip, which increases as the motor is loaded. The synchronous motor receives power from the circuit much as a shaft receives power through gearing—the speed is absolutely and rigidly fixed by the driving power. On the other hand, the action of the induction motor is like that of a pulley driven by a belt—there is flexibility, slip; a heavy load does not break gear-teeth nor throw the motor out of step. There is simply greater slip, and nothing is to be feared until belt or motor begins to smoke.

The alternating current motor is not only used in connection with long distance transmission where alternating current is essential, but is finding a widening field in the operation of factories and mills. "The Economic Advantages of Electric Power for Driving Tools" was treated by Prof. Fessenden at the September meeting, 1896. The highest excellence is required in the alternating current motor for entrance into the field which the direct current motor has so efficiently occupied but that excellence is found in mechanical construction and in simplicity of operation.

The description of the motor is negative—no commutator, no collecting rings, no brushes, nothing to handle but the switch, nothing to wear but self-oiling bearings, no exposed parts, no danger from fire. The alternating current with its profound and intricate theoretical properties and polyphase currents with their confusing relations and reactions have produced a motor of almost ideal simplicity.

There is a perplexing characteristic of alternating currents especially notable in motor work, which may be illuminated by an analogy. When I ride my bicycle, pushing down

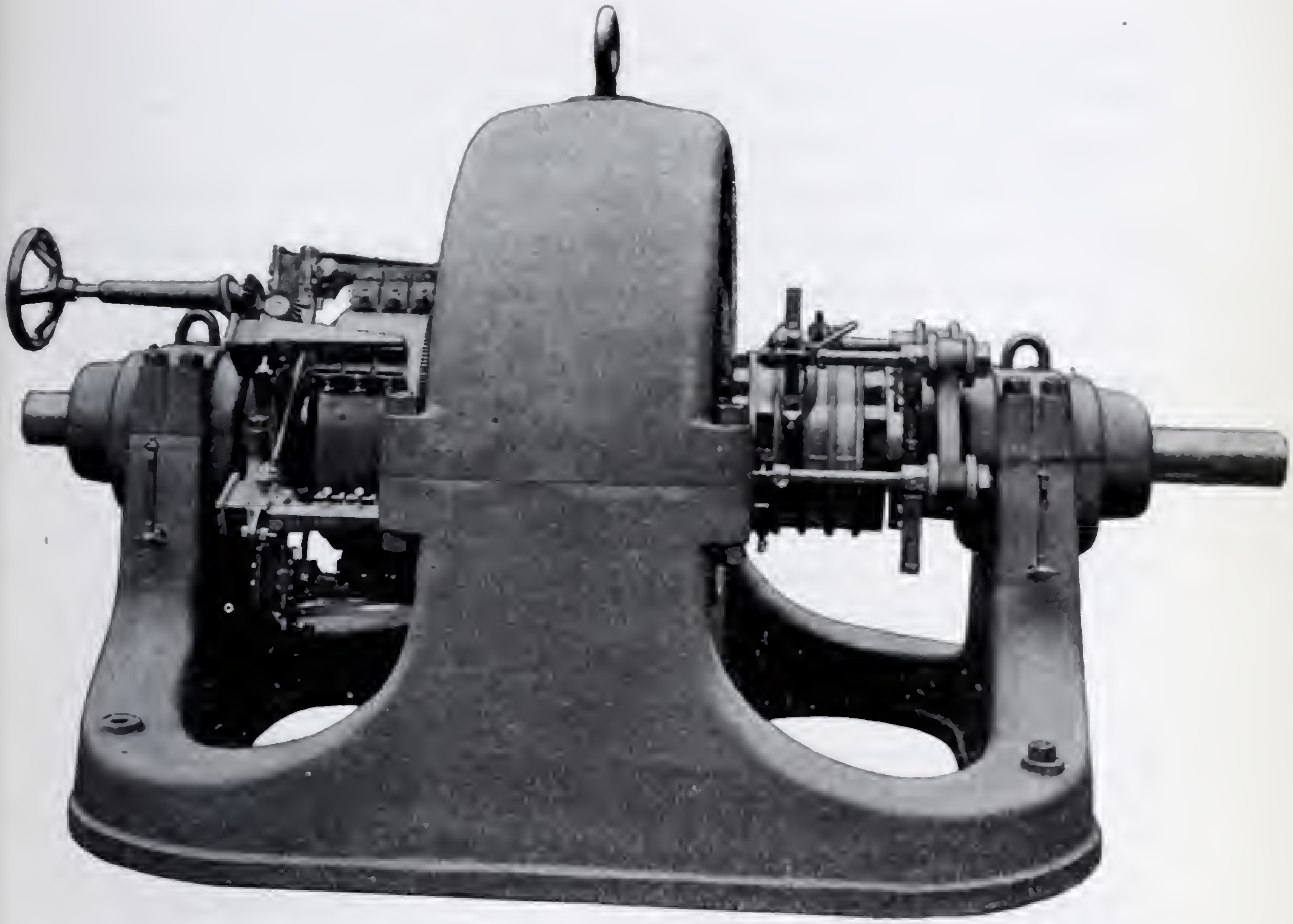
on descending pedals, I work as an alternating current generator. If I back pedal, throwing my weight on ascending pedals, the machine does work on me, the action is that of a motor. Now if I throw my weight on a pedal which has descended half way, and keep pushing through a half revolution until it reaches the horizontal again and then throw my weight in the same way upon the other pedal, the work done in one quarter revolution is restored in the next, the net result is nil, although the friction loss in muscles and bearings may be as great as ever. This corresponds to a lag of 90°, or a difference of 90° between current and electromotive force, i. e., between flow and pressure, or in the blcycle between motion and push. Between the extremes of perfectly advantageous and completely ineffective action there are all degrees of gradation.

This is usually expressed as a "power factor," which is the ratio between the current which actually flows and the current which would do the same work if it were in phase with the pressure. "Apparent" power is current multiplied by pressure; "true" power is apparent power multipled by the power factor. Apparent efficiency and true or real efficiency are found by dividing the power which the motor delivers by the respective kind of power which the motor receives.

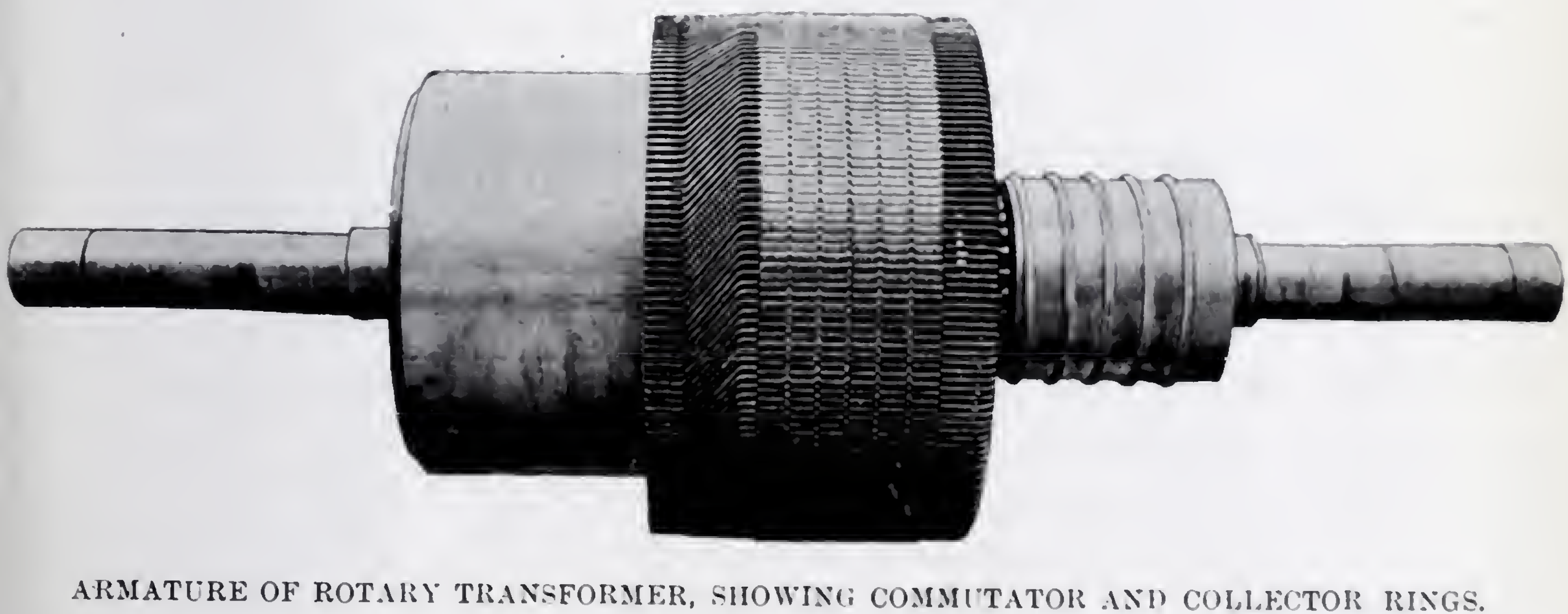
TRANSFORMATION FROM ALTERNATING TO DIRECT CURRENT.

While the alternating current holds almost an exclusive field for transmission, the direct current alone is applicable to electrolytic work and storage batteries. It only is used for ordinary street railway work, and it possess some advantages in central stations and for isolated lighting.

An electric system may combine the advantages of both systems if alternating current be transformed into direct current. This can be effected by an alternating current motor driving a direct current dynamo. This may be greatly simplified in a machine, commonly termed a rotary transformer, which acts simultaneously as motor and as dynamo. A single armature winding is connected to collecting rings for



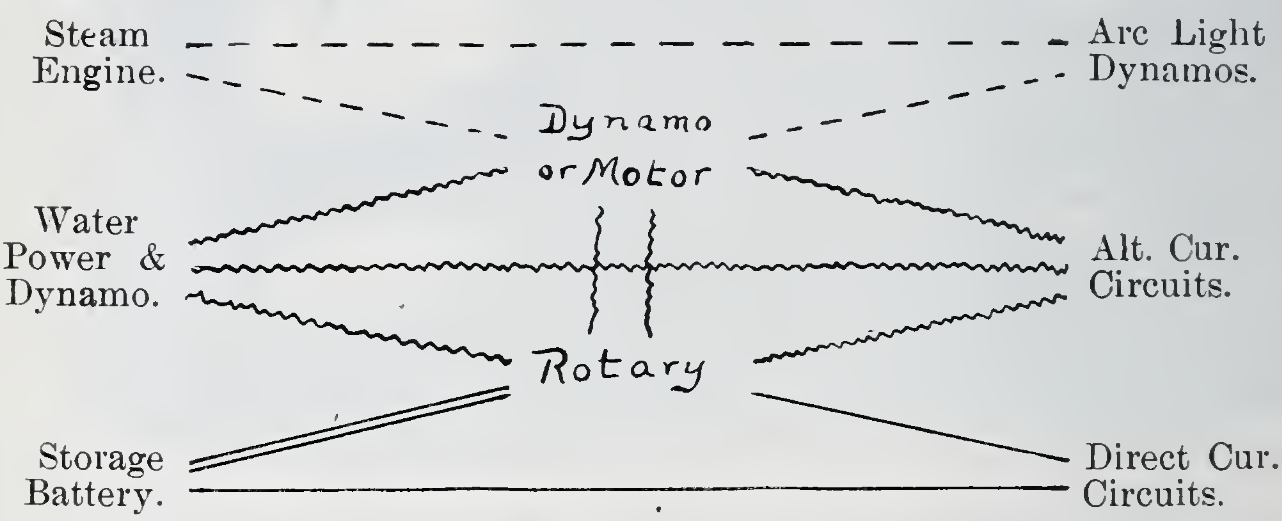
ROTARY FOR TRANSFORMING ALTERNATING INTO DIRECT CURRENT.



ARMATURE OF ROTARY TRANSFORMER, SHOWING COMMUTATOR AND COLLECTOR RINGS.

receiving alternating current and also to a commutator for delivering direct current. The machine is at once a synchronous alternating current motor and a direct current dynamo.

The electromotive force of the alternating current received and of the direct current delivered bear a definite ratio. The pressure of the direct current can therefore be varied by changes in the alternating pressure. These are secured by increasing or decreasing the number of turns in the step-down transformers which supply current to the rotaries. This is of especial value in electrolytic work and in charging storage batteries.



PATHS OF POWER AT HARTFORD PLANT.

- - - - - - Mechanical Power.
〰〰 Alternating Current.
——— Direct Current.
Single lines—Power from left to right only.
Double lines—Power in either direction.

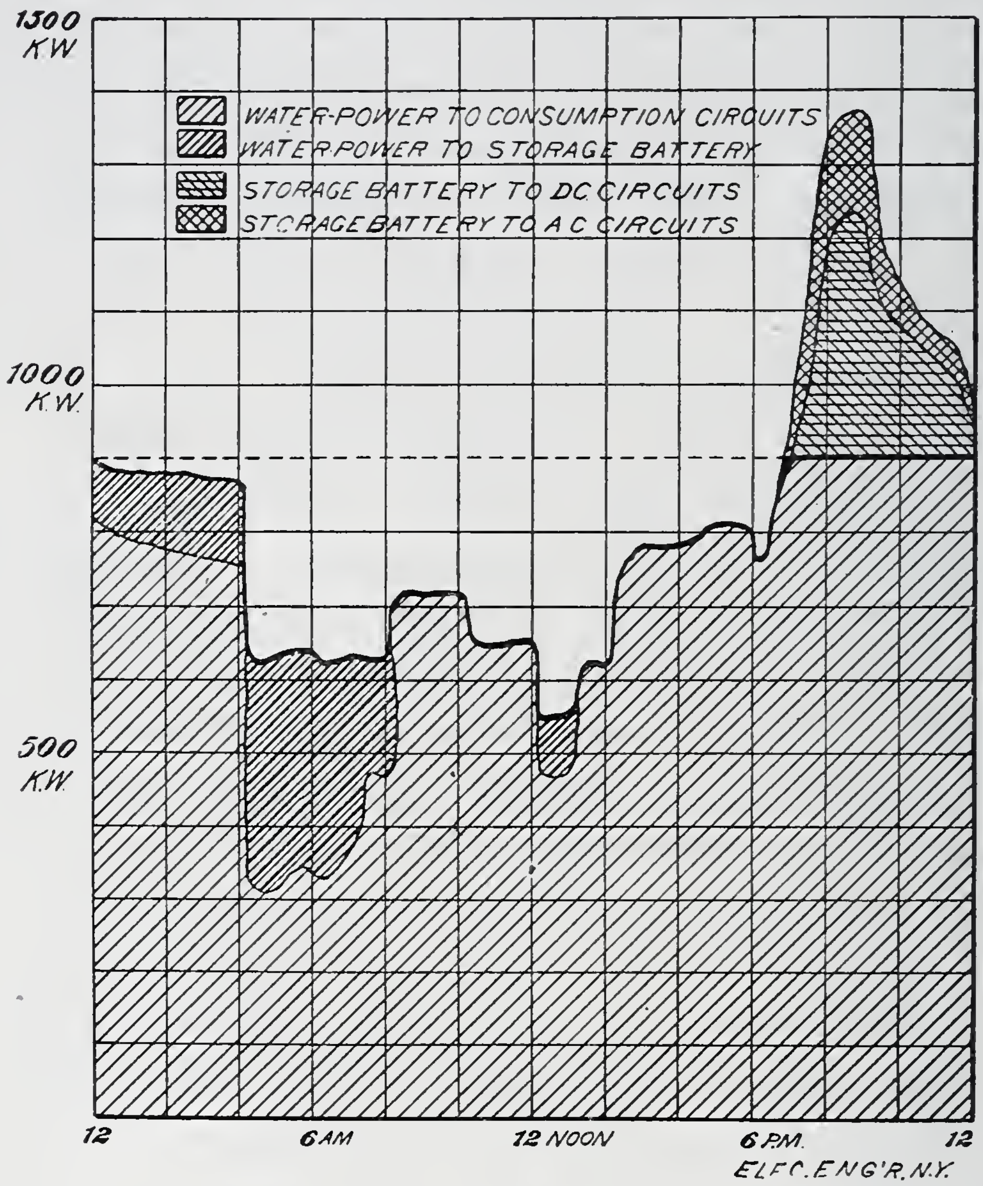
THE PLANT AT HARTFORD.

The electric plant at Hartford, Conn., is unique in the variety of apparatus which is combined into a simple, comprehensive system. There are two sources of power—steam and water power. The latter drives generators delivering two-phase current, which is transformed into three-phase current and transmitted over a distance of ten miles to the city, where it is retransformed into two-phase current at about 2,000 volts.

Power is delivered in three forms—for arc lighting, for alternating current service and for direct current, 220-volt,

three-wire distribution. The power for arc lighting is secured either from the water power through the agency of an 800 H. P. synchronous motor, which may be connected to the shaft which drives the arc machines, or it may be secured from the steam engine by coupling it to the counter-shaft. The power for the alternating current circuits may be taken from the long distance transmission circuit, or it may be secured from the engine if the latter be connected to drive as a dynamo the machine which is ordinarily used as a synchronous motor, or in another way which will be explained presently. The three-wire direct current circuits receive their current from two 333 H. P. rotary transformers. The rotaries are operated from the alternating current circuts, and therefore receive their power from the water wheels or the engine. The rotaries supply direct current both to the distributing circuits and to the storage battery. The storage battery may deliver current either to three-wire distributing circuits or to the rotary. In this case the rotary transformer current may be used for supplying the alternating current circuits, or for driving the synchronous motor for running the arc machines. The storage battery is therefore a third source of power which is available for supplying all of the three kinds of circuits which are operated by this company. The e. m. f. of the rotary is controlled by a regulator which varies the ratio of the transformers which supply it with current. The e. m. f. may be varied by gradual steps from about 220 to 330 volts, thus enabling suitable adjustments to be made for charging the battery or causing the battery to discharge back through the rotary into the alternating circuits. The middle wire of the three-wire system is secured from the middle point of the secondary coils of the transformers which supply current to the rotaries. A rotary with only two sets of brushes on the commutator transforms between a two-phase alternating current circuit and a three-wire direct current circuit, and by means of a simple regulator the e. m. f. can be varied over a wide range.

A curve showing the average load for the six effective days of a week in May has been prepared. The engine is a reserve which was not called upon during the whole week. Beginning at midnight the power is used for charging the storage battery and for supplying the various commercial circuits,



LOAD CURVE AT HARTFORD PLANT.

principally the arc lighting, which continues until daylight. The load is less during the day and the storage battery is charged during part of the time. In the evening the increased load soon reaches 900 K. W. (1,200 H. P.) and the storage battery is now called upon to supply all of the three-wire direct current service, also a part reaching a maximum of 150 K. W. of the alternating current service. The storage battery has enabled a maximum load of nearly 1,500 K. W. to be

handled by a water power of 900 K. W. The load upon the distributing circuit varies from about 300 to 1,500 K. W., while the actual load upon the water wheels has varied from about 600 K. W. to 900 K. W.

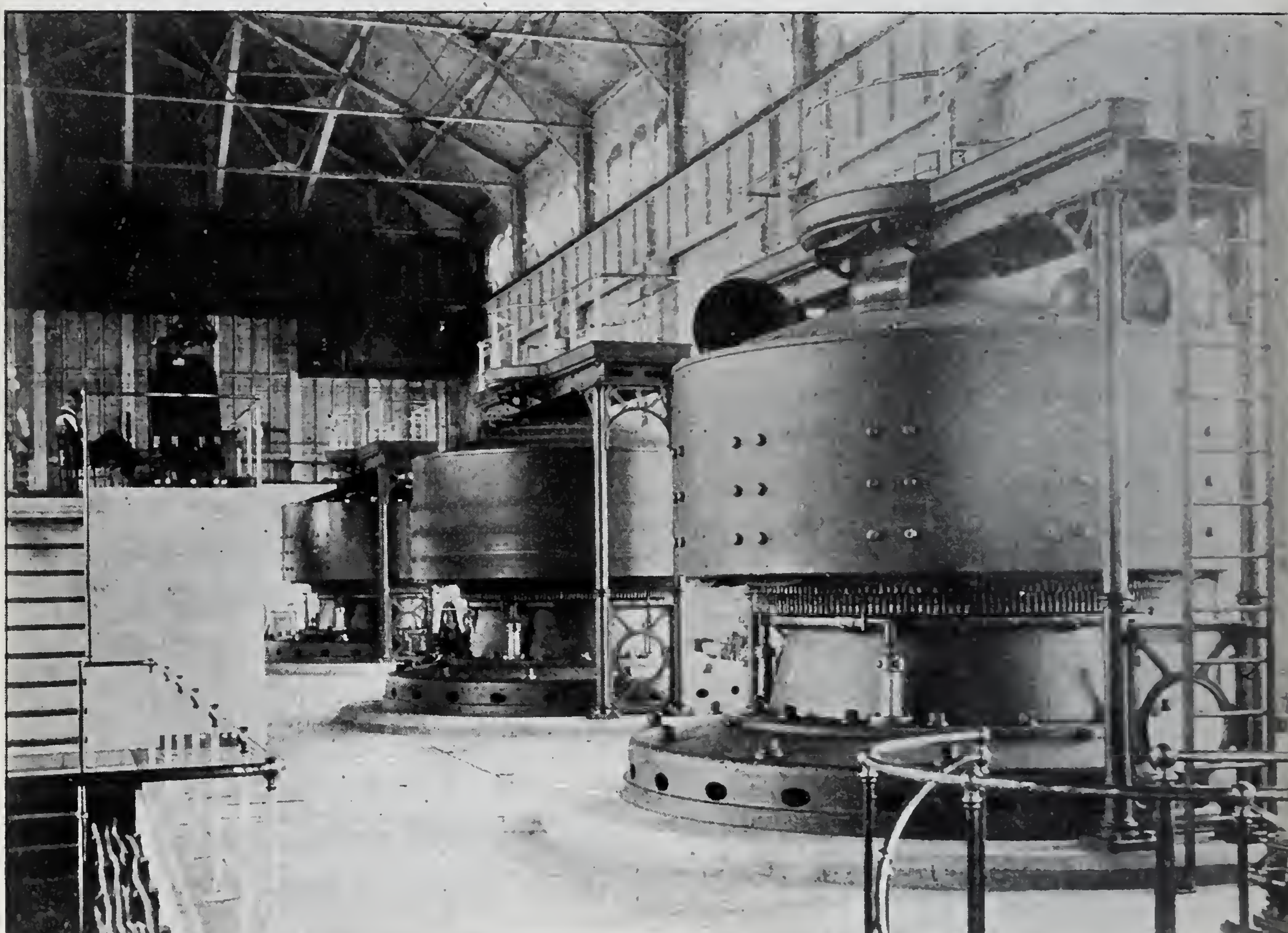
This plant is of especial interest as it marks the beginning of what will doubtless be an important factor in central station practice—alternating current transmission and rotary sub-stations with storage batteries.

THE PLANT AT NIAGARA.

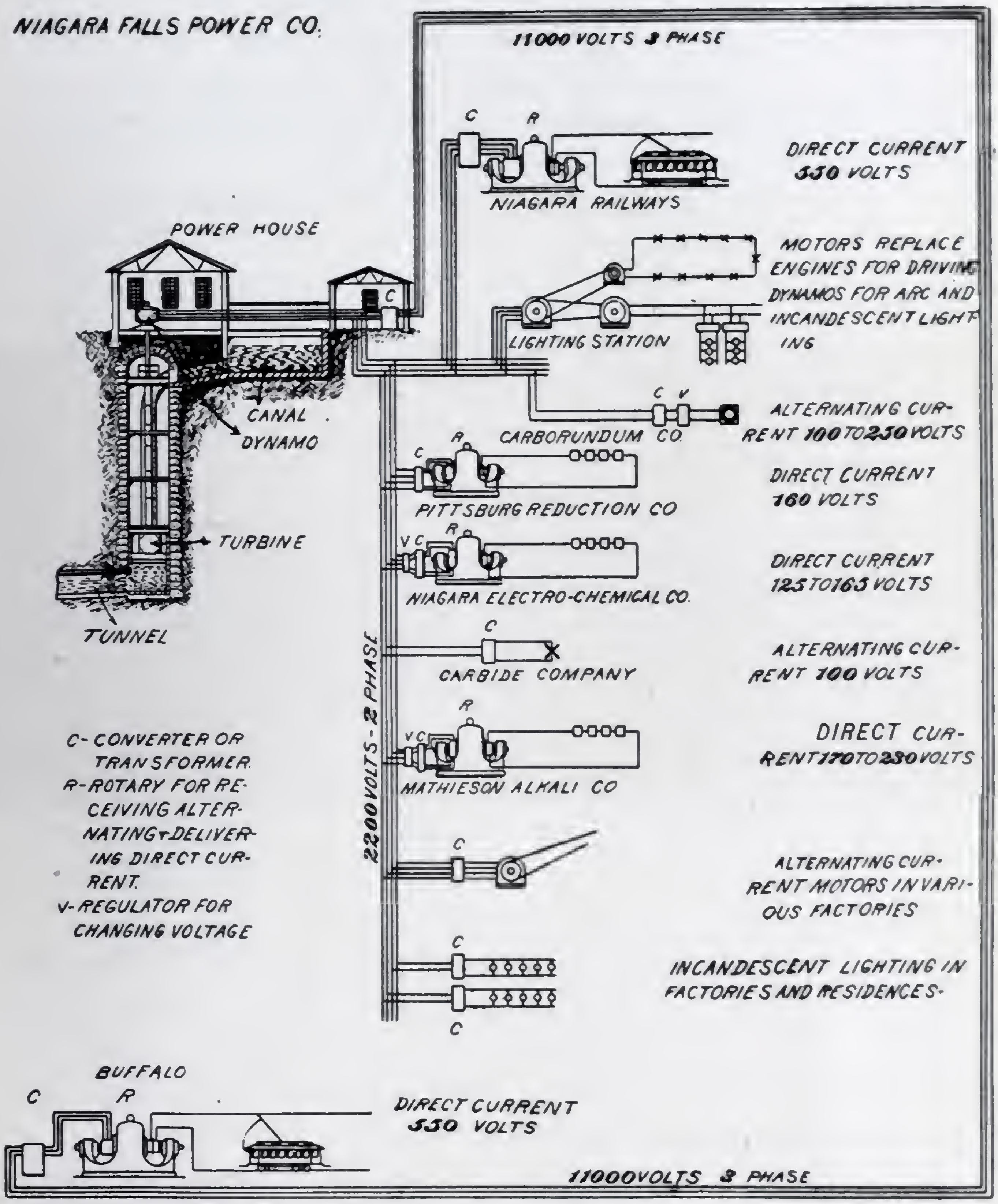
The general features of the great plant of the Niagara Falls Power Co. are well known. The installation presents engineering projects of great magnitude, an electric system of great versatility and flexibility and an aggregation of new industries. These features can be most concisely presented by a diagram which the writer recently prepared for the Engineers' Club of Philadelphia, and by a few paragraphs of comment.

"The current from Niagara generators is supplying almost every kind of electrical industry. It is transformed into direct current at constant voltage and at variable voltage. It is transformed as alternating current to a low voltage, either constant or variable, and to a high voltage for transmission—from two phases to three phases. The current is used for developing mechanical power which replaces steam engines, does miscellaneous work and operates street railways. The current is used for lighting and for ordinary heating. In the new processes it is used for its electrolytic and heating effects. Heating is produced both by direct passage of the current through materials sometimes in liquid, sometimes in solid form, and by the electric arc.

"The important enterprises at Niagara are new. The processes are among those which electricity has so recently given to the arts. They are large consumers of power, and their commercial practibility depends upon its cheapness. In ordinary manufacturing industries the cost of power is a small



NIAGARA POWER HOUSE.



TRANSFORMATIONS AND APPLICATIONS OF NIAGARA POWER.

percentage of the cost of material and labor, and the power is used only a small part of the day. In the industries at Niagara the cost of power is the vital element, and while on the one hand their continuous operation make them ideal customers of a water power plant, on the other hand they are significant omens of the advance in industrial methods which is made possible by abundant and cheap power."

ERRATUM.

In the published Proceedings for October, page 423, sixth line from the bottom, read arsenic and phosphorus, instead of arsenic and antimony.

DISCUSSION OF MR. SCOTT'S PAPER.

(Paper published in November Proceedings.)

MR. PECK—Which A. C. motors, synchronous or induction, are used in the Westinghouse works?

MR. SCOTT—Induction motors. Synchronous motors are not well adapted for small units. There are different types of induction motors, sometimes the primary element revolves (the current passes from the circuit to the motor windings through brushes resting on collector rings,) and sometimes it is stationary and the induced or secondary element revolves. At first the former type was common, but of late the latter is used almost entirely, and is the one described in the paper which has just been read.

MR. PECK—How much starting torque does an induction motor give?

MR. SCOTT—The motor which is illustrated and described can give four to five times the full load torque. In fact, the purpose of the starting apparatus is to cut down the torque.

MR. PECK—Do I understand that there is no moving wire at all on an induction motor? In one inductor machine described this statement is made.

MR. SCOTT—The machine you refer to is a generator, not a motor. This confusion of terms is unfortunate. The revolving element of the *inductor* generator has no moving wire; the revolving element of the *induction* motor has copper windings, which have no connection with any other circuit.

MR. PECK—I read in the papers that a company is installing a plant for 75,000 h. p. in northern New York. What do they want so much for? Is there any special demand for it there?

MR. SCOTT—There is little present demand, but it is intended that companies needing large amounts of power will

locate there. It may be noted that only a small per cent. of the power produced at Niagara Falls is used in Buffalo, the remainder being used by industries which have located at Niagara Falls.

Mr. Fisher—I do not know when I have enjoyed a lecture so much as this one. Mr. Scott has the happy faculty of making everything he discusses so clear and simple. There is one question I would like to ask. How are the two phase currents changed into the three phase currents? Are rotary transformers used?

Mr. Scott—No, they are obtained from stationary transformers without rotary parts. The method may be readily seen if we consider for a moment the exact nature of the transformation.

If an armature with a single coil of wire revolves in a field having, say, two poles, an alternating E. M. F. will be induced in the coil. During half a revolution the pressure will be in one direction and during the other half in the opposite direction. If a second and similar coil be put on the armature 90° from the first coil, so that the second coil sustains exactly the same relations to the field poles as the first coil, but always passes under the poles a quarter of a revolution later, then the currents from these two coils—separate currents, having their own individual circuits, each acting for itself very much as if the other did not exist—are termed "two phase" or "quarter phase," or "90°" currents and are the basis of the two phase system. If there be three coils on the armature, equally displaced by angles of 120°, so that each coil follows the preceding one in passing under the field poles after one-third of a revolution, then the three currents from these coils form the basis of the three phase system. The three circuits may supply their own loads, and are in great measure independent of one another, although they use common wires—*e. g.*, the first coil may be connected to its lamps or outer load by the wires *a* and *b*, the second coil by *b* and *c*, and the third by *c* and *a*, a total of three wires.

Now, suppose that the armature with two coils at 90° be connected in series. Both coils now contribute equally to produce a single current, which will flow later than the normal time of one of the coils and earlier than that of the other—*i. e.*, at the time when current would flow in a coil placed on the armature in the midway or 45° position.

If the two coils at right angles have unequal number of turns, then the result will not be equivalent to a coil at 45°, but at some other angle. The result may be found by a diagram similar to the parallelogram of forces in mechanics. The sides of the parallelogram are to be drawn at an angle equal to the angular displacement of the coils on the armature, 90° in the present case, and proportional to the number of turns in the respective coils. The diagonal of the resulting parallelogram represents, in direction and magnitude, the position and number of turns in a coil which would produce the same current as that actually produced by the two coils in series. As any relative number of turns may be taken, it is possible to combine two coils which differ 90° in position (or "in phase") so as to produce any phase whatever—*e.g.*, they may be selected in the proper ratio for producing a difference of 120° from one of the coils, corresponding to the displacement of the coils in the three-phase winding.

Now, in the two-phase-three-phase transformation in transformers the primary coils in two transformers are connected directly to the two circuits from a two-phase armature. The pressures induced in the secondary coils differ in phase 90°. These windings are combined by connecting the middle point of one winding with one end of the winding of the other transformer, which has 86.6% $(=\frac{1}{2}\sqrt{3})$ of the number of turns on the first transformer. The pressures or E. M. F.'s between the three pairs of free ends are all equal, and differ in phase by 120° respectively.

The direction and magnitude of the two secondary E. M. F.'s are shown by the solid lines in the accompanying dia-

gram. The resultant E. M. F.'s are shown by the dotted lines. If three lamps be connected between the respective pairs of terminals it would be found that the successive turns of maximum current in the several lamps are the same that they would be if the lamps were connected to the three circuits from a three-phase armature.

The reverse transformation from three phases to two phases is made in the same way. The object of phase transformation is to secure three phases for transmission, which require but three wires and effect a saving of 25% in copper, and two phases for distribution, which is best for electric lighting.

Mr. Hall—Speaking of regulation, what is the permissible variation in speed during a revolution in such a plant as the Allegheny County light plant?

Mr. Scott—The variation must be very slight. To take a mechanical analogy, if two engines be geared to a shaft and one tends to run slower, the other will do all the work. There will, therefore, be a stress set up in the gearing due to the tendency to difference in speed.

So in dynamos geared electrically. If there is a difference of speeds, one engine will do more work than the other. If the two engines run at the same average speed, but during part of a revolution one advances and during another part the other advances, then there is a see-saw action. When the engines drive alternators which are connected together, the effect is to give a flow of current between the machines, and the permissible variation of speed is that variation which will give that amount of flow between the dynamos, which can just be neglected. If the allowable displacement of the armatures be 1-10 of the distance between two poles, then in such machines as those of the Allegheny Light Company, with 62 poles, it is evident the variation in angular position must not exceed one six-hundred-and-twentieth of the circumference.

President—Can power, arc lights and incandescent lights be taken from the same machine? To take an instance, can one hundred horse-power of motors, one hundred horse-power of arc lamps, and one hundred horse-power of incandescents be run from the same machine?

Mr. Scott—Yes. This method is now in use.

Mr. Bole—Mr. Scott spoke of the difficulty of running generators in synchronism, and of the difficulty of getting engines to stay in exact step. Does Mr. Scott know of any large station or plant using large units in multiple?

Mr. Scott—A number of smaller stations are now run in parallel both with belted and direct driven generators, and a number of large plants now being constructed are being laid out with a view to being run in multiple, but I do not know of any near here that are now running.

Mr. Bole explained the difficulty by a mechanical analogy, and stated that he knew of stations intended to run in multiple, but of none actually running so. He asked Mr. Scott whether he knew of any plant of two thousand horse-power or more actually running, and whether he considered it would be possible to overcome the difficulties in the dynamos which at present existed.

Mr. Scott—I do not know about the engines, but the dynamos are all right. In the Niagara Falls plant the generators of five thousand horse-power run regularly in multiple.

Professor Fessenden—Is it not a fact that the whole trouble is due to the fact that the engines govern too well? In England, for instance, they do not know how to build engines to give what we should call good regulation. Here we build engines as a usual thing to regulate with a variation of one, and even one-half of one, per cent. In England, they have excited discussions in the technical papers as to whether it is possible to build engines to regulate to two per cent., and have only recently begun to copy our methods in this respect. Now, in the old days of alternating current lighting, Gordon, who was

a great engineer, built an A. C. plant and ran his dynamos in parallel. These were big units, and he had no governors on his engines. He had a small room, with a photometer in it, and an incandescent lamp run off from the lighting circuit. The handle of the throttle valve of an engine came into each room, and when the light got too dim the man in there opened the throttle a little. If it was too bright, he closed it. The plant ran perfectly, and the engines and dynamos settled the question of the division of load amongst themselves. The thing you want to regulate in parallel running is not the variation of speed between engines, but the variation of steam. Then the variation of speed will take care of itself.

(Note added afterwards.—Consequently I would make the following suggestion for a station for parallel running. Get engines of the same type and dynamos of the same wave form, preferable sine wave, and of same inherent regulation. Disconnect governors from engines. Have one governor, regulated by the voltage, a mechanical or electric governor. A capacity in series with an inductance makes the most sensitive governor, as I have pointed out elsewhere. Run all the valve gears from this central electric governor, so that each engine has the same proportionate amount of steam as the others, i. e., opens and closes at the same portion of the stroke. Then the different units will settle the phase shiftings amongst themselves, and as each engine has the same proportionate amount of steam, it will do its share of the work, and the main governor will keep the voltage constant and regulate the total amount of steam used. In case of accident to the regulator of any engine, the admission should be so arranged as to be shut off and the exhaust opened, the dynamo then acting as motor, and driving the engine.)

Mr. Scott—There are two distinct points to be considered in regulation, one is uniformity in speed, the other is the variation in speed with different loads. The first I have already spoken of. The second has been referred to

by Professor Fessenden. Close speed regulation between no load and full load is not a necessary condition for multiple running of alternators—it may be quite the opposite. For example, if an engine has a speed of 101 at no load and 100 at full load, and a second engine runs at $100\frac{1}{2}$ with no load and $99\frac{1}{2}$ at full load, the regulations may be said to be very close and the two engines may be justly regarded as having practically the same speed. But if they be running alternators in multiple, and the load is equal to half the load of one machine, the speed will be $100\frac{1}{2}$, which will be carried entirely by one engine. If the load is increased until the speed is 100, then one machine will carry full load and the other half load. On the other hand, if each engine fell off two or three per cent. at full load, the loads would be divided much more nearly equally.

Engineers' Society of Western Pennsylvania.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS

The regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society's house, 410 Penn Avenue, at 8.25 P. M., Tuesday, December 21, 1897. There were 51 members and visitors present.

For the Board of Direction, the Secretary reported the names of the following applicants as passed by the Board, and to be voted upon at the next regular meeting.

William M. Faber, Ass't Sales Agent.
Harry Heffrin, Engineer.
Henry F. Miller, Mechanical Engineer.
David L. Moorhead, Civil Engineer.
Wm. J. McAllen, Draughtsman.
J. Mont. McCrickart, Mining Engineer.
Charles T. Rainey, Mining Engineer.
Samuel A. Taylor, Civil and Mining Engineer.

For the Committee on the Dalzell bill, Mr. Morse gave a brief history of the bill to date, and of the action of the committee, stating that the bill was likely to come up about the first part of January.

It was voted that the committee be held over to the next year.

In answer to a question, the President stated that the bill was the same, no changes, except in unessential matters, having been made in it.

For the Banquet Committee, Mr. Engstrom stated that the date of the banquet had been fixed for Thursday, January 27, and that the price of tickets would be $4.00. When the other arrangements were made, members would be notified by mail. A balance of $3.40 was left over from last year's banquet.

The President took occasion to remind the committee in regard to inviting the presidents and secretaries of some of the other prominent engineering societies.

For the Nominating Committee, Colonel Roberts, in the absence of Mr. Johnson, reported as follows:

PRESIDENT, One Year, G. S. Davison.

VICE PRESIDENT, Two Years, W. A. Bole.

DIRECTORS, Two Years, C. F. Scott, Gustave Kaufman.

SECRETARY, One Year, R. A. Fessenden.

TREASURER, One Year, A. E. Frost.

For Committee on Power, Mr. Fisher reported that out of 600 or 700 applications sent out, answers had been received from only 3 per cent., and that two-thirds of these were not complete enough to be of any use. They had, however, the promise of some good reports, and hoped to have something to report soon.

It was voted that this committee also be carried over to the next year.

For the Committee on Roads, Mr. Schellenberg said that at some future time the committee would make a third report.

The President here appointed Messrs. J. K. Lyons, Gustave Kaufman, and J. R. Elliott as the committee to audit the accounts of Prof. A. E. Frost, Treasurer.

The paper of the evening, "Alternating Currents—Some Recent Advances," was then read by Mr. Scott.

(This paper was published in the November Proceedings, pages 457-488.)

(For discussion of this paper see pages 489 to 495.)

A vote of thanks was tendered Mr. Scott for his admirable lecture, and the great part taken by the Westinghouse Company and its engineers in the development of the alternating current system was commented on. The meeting then adjourned, at 10.40 P. M.

REGINALD A. FESSENDEN,
Secretary.

MEETING OF THE CHEMICAL SECTION.

PITTSBURG, PA., December 23, 1897.

The regular monthly meeting of the Chemical Section was held at 410 Penn Ave., December 23, 1897. Chairman, W. E. Garrigues. Attendance, 16.

The minutes of the last regular meeting were read and approved. Mr. J. O. Handy, for the committee on chemical literature, reported an abstract of recent papers which were briefly discussed by those present.

Mr. Camp for the committee on nominations reported as follows:

Chairman, J. O. Handy.

Vice-Chairman, Dr. Walther Riddle.

Directors, Dr. K. F. Stahl, W. E. Garrigues.

Secretary, A. G. McKenna.

The paper for the evening, "A Brief Review of the More Important Series of Artificial Organic Dye-Stuffs," was then read by Dr. E. S. Johnson. After the discussion of the paper the Section adjourned at 10.45 P. M.

A. G. MCKENNA,
Secretary C. S.

A BRIEF REVIEW OF THE MORE IMPORTANT SERIES OF ARTIFICAL ORGANIC DYE-STUFFS.

BY EDWARD S. JOHNSON.

Prominent among the secondary qualities of matter capable of powerful appeal to man's esthetic sense, without distinction of race or degree of culture, is that of color. Its perception in pleasurable form by primitive man, represented in a measure by the barbarous tribes of the present, must first have found

means of voluntary exercise in the easily accessible, brightly colored products of nature ; with these he decorated his person and surroundings.

With the advance of time, intelligence increased, and, with it, a keenness of observation and an ingenuity, which discovered and applied still other, in part, more difficultly approachable substances, notably mineral and botanical, to beautification as accomplished in color. The ancient civilizations of Egypt and the Orient have handed down to succeeding generations and nations, through tens of centuries, a goodly store of such materials. Replete with interest among them, members of a peculiar class of bodies, are two of the famous coloring matters of antiquity and the present, indigo and madder. Of more recent discovery and application, likewise arising in the economy of organized living matter, are colors extracted variously from woods, herbs, lichens, and insects, in all comprising the not exceedingly numerous list of modern *natural* dye-stuffs.

Less than fifty years ago, the dyer was solely dependent upon these natural sources of supply for the essential materials required in the practice of his craft. Within this period a great chemical industry has been established. Its foundation is upon principles which underlie the substantial and rapid progress pre-eminently characterizing the highest form of existing civilization, the principles of the inductive method for the perception of truth. Its development in rapidity and in literal and influential magnitude has been phenomenal, and marks it, it may be said without exaggeration, as the industrial wonder of the century. Its products, the chemical transformations of a once waste and burdensome by-product of the gas manufacture, are the re-agents, with few exceptions to the exclusion of those of nature, in the hands of the modern colorist for the creation of the multifarious and brilliant effects for which his decorative art is distinguished. It is needless to add that I refer to the manufacture of the *artificial organic dye-stuffs*.

To present this remarkable class of substances briefly and in a manner otherwise adapted to the occasion will be the effort of the sequel. Having their origin, as intimated and popularly known, in materials separated from coal-tar, the products of the distillation of the latter, the *raw materials* of the manufacture, will be a main subject for consideration. This will preface a treatment of the *coloring matters* themselves, in the course of which their *chemistry*, *manufacture* illustratively, and *application* will be discussed.

I fully appreciate the difficulties of the task before me of sketching intelligibly and interestingly so comprehensive a theme, and yet in mere outline; it is only with the felt assurance of a lenient criticism that the work is undertaken.

I. The Raw Materials and Intermediate Products of the Manufacture.

HISTORICAL.[1]

Toward the end of the seventeenth century, the attention of the people of Europe was being drawn to its vast deposits of bituminous coal. That this substance would burn was a matter of popular information, but, in the illy adapted heating appliances prevailing at that period, its consumption, in the household more especially, was attended with discouragingly unpleasant exhalations. It was desirable, and further becoming a matter of political-economic importance, to find substitutes for wood and charcoal as fuels.

Men of inventive genius gave the subject thoughtful consideration which, naturally enough, was concentrated upon a solution of the problem by means of a utilization of the seemingly exhaustless deposits of a combustible natural product. Among them was the distinguished German alchemist, Johann Joachim Becher, then a resident of England. In the archives

1. Compare Schultz: *Die Chemie des Steinkohlentheers*. Lunge: *Die Industrie des Steinkohlentheers u. Ammoniaks*, and references quoted by them.

of the English patent office has been found a proposal by Becher, the earliest in the interest of the "refining" of coal, and, according to the notion of the time, adapting it to use as a fuel. In the same connection, the inventor called attention to the tar formed in the refining process and to its possible applicability to purposes hitherto served by wood-tar. The main object, however, as explained by the author[2] was to "burn" turf and bituminous coal to "good coal which no longer smokes or stinks," but is suitable for use in the house and for smelting. Becher secured protection for his process in England in the form of letters patent, the first issued by that government in the interest of the destructive distillation of coal. The intentional preparation of coal-tar, thus first suggested, as an industrial product seems to have been soon abandoned, and was not revived until many years later, in 1768, when it was manufactured as a coke-oven by-product in the coal regions of Germany by the chemist Stauf; a few years after, in 1781, it seems to have been made in England by a process of the noted inventor, the Earl of Dundonald, but scarcely in quantities considerable enough to warrant the name of manufacture. Coke was the chief product of the coal industry, and, heavily demanded by the constantly expanding metallurgical industries of Europe generally but particularly of England, it remained essential and increasingly important. The production of tar continued to be a matter of small industrial consequence, more especially because of its limited application, and further because coke formed in destructive distillation with much tar was found of inferior quality to that made under conditions generating less tar.

The close of the eighteenth century was the beginning of a new epoch in the history of coal-tar. It was about this time that the idea of applying the combustible gases produced in the dry distillation of coal was conceived by Wm. Murdoch in

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2 Lunge: *Die Industrie des Steinkohlentheers*, p. 3. The words quoted are translated from Becher's *Närrische Weisheit*, Nr. 36., as reproduced by Schultz: *Die Chemie d. Steinkohlentheers*, 2te Aufl., p. 5.

England, and almost simultaneously by the Frenchman Lebon. Murdoch, however, is properly regarded as the founder of the gas industry. It was through his efforts and those of his energetic pupil and supporter, Samuel Clegg, that illuminating gas was made an industrial possibility. In 1813 the new

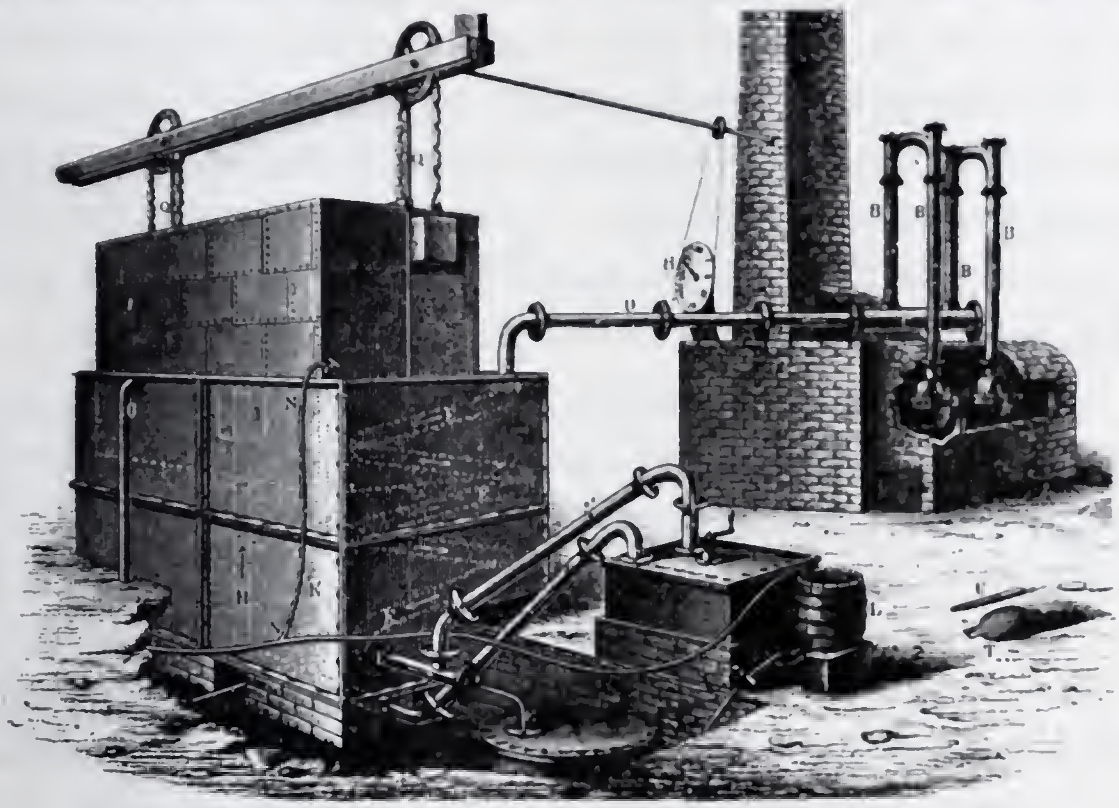


Fig. 1.
Gas plant as designed by Samuel Clegg at the beginning of the present century.[1]

illuminant had been introduced into London; Paris and other European centers followed in its adoption within a few years, and the turn of the first half of the present century saw its general reception throughout the civilized world.

Attending the manufacture of coal-gas, the production of tar, from the modest beginnings established by Becher, had grown thus to the seemly proportions of probably several hundred thousand tons yearly, as a necessary and comparatively useless by-product of the manufacture.

Hitherto its application *in crude form* had been confined to the saturation of paper for use in building, the impregnation of wood as a preservative, and the protection of metals against corrosion as a paint. The rational method of later

1 From Schultz: *Die Chemie des Steinkohlentheers.*

years for contributing to the disposal of a surplus, that of consumption as fuel under the retorts, had as yet not been extensively practiced. On a small scale it had been subjected to fractional distillation, and *the distillates*, besides for purposes just mentioned, variously used as substitutes for turpentine, for lamp-oil, as solvents for rubber, in the cleaning of clothing, and perhaps in other similarly insignificant ways, so far as the removal of the superfluity of tar from the great tanks of the gas-works was concerned. The refined pitch, the residue of the distillation was possibly the main product of the few established distilleries.

Constantly accumulating and with little appreciable expansion of its limited usefulness, the question of its disposal, vexatious and expensive, was becoming for the manufacturer one of greatest economic moment.

In the century and a half which have now elapsed since the days of Becher, radical changes in the philosophy of the natural sciences have become manifest.

In chemistry the reign of alchemy had passed, Stahl's phlogiston theory had been outlived, and chemical investigation was under the guidance of the new philosophy whose motto is, "Observation, experiment, generalization," and greatest achievement, the establishment of the grand principle of the conservation of energy.

The association of the ideas, "inductive philosophy," and "coal-tar in its industrial evolution," may, for an instant, seem forced. More mature consideration, nevertheless, will discover an intimate relationship, that of cause and more or less direct effect. Armed with the new conception and enthused by its magnificent results from the time of Lavoisier on, investigators were grappling with the many problems of pure and applied chemistry which the systematic work and the exigencies of the period brought forth. Much interest and energy, notably in immediately succeeding decades, had been enlisted in the destructive distillation of coal and allied natural sub-

stances, the scientist, with a view to an understanding of their nature, and the nature and mode of formation of the compounds present in the distillates and other decomposition products of the process; the technologist seeking to apply them.

The tar of the gas factories was an object of incessant and untiring research, with results which have surpassed the expectations of the most sanguine, and were destined to a splendid future, foreseen in a measure with remarkable accuracy by the genius of Liebig. In his famous "Chemishen Briefen" are found the following prophetic words[3]: "We believe that the time is near when some one will discover a process for the preparation . . . from coal-tar, of the glorious dye-stuff of madder, benificent quinine or morphine." In artificial alizerine literally and in antifebrine, phenacetine, and antipyrine in effect, the prediction has had a striking, more than partial, fulfillment.

The first discoveries among the large number of bodies since isolated from coal-tar disclosed, as early as 1834, strangely enough, the presence of *aniline*, a compound occurring in the tar in minute quantities. Its discoverer was Runge who named it cyanol. Before and after this time, the same body was derived from other sources by other investigators without a general recognition of identity. The subject engaged Hofmann's attention, and it was he who demonstrated that the several preparations differed only in name. His researches, aside from their purely scientific value, call for special remark as having brought coal-tar the more prominently to notice in scientific circles,

The occurrence of *benzene* in coal-gas had already been noticed by Faraday in the course of his investigations upon the compressibility of gases. By Hofmann it was found to be also a constituent of the tar of the gas-works.

Shortly afterward another important compound, *toluene*, was recognized by Mansfield, a pupil of Hofmann, as an associate of benzene and its homologue.

3 Liebig: *Chemische Briefe*, 6te. Aufl., p. 35. Free translation.

Still the uses of coal-tar remained restricted.

In 1856 Perkin discovered the first of the aniline dye-stuffs, *mauveine*, Perkin's violet. Phenomenal success attended its introduction; within three years a reception throughout Europe had been assured it, regardless of the fabulous price[1] (that of platinum) commanded by the preparations first placed upon the market. The demand for the raw material of the manufacture, aniline, became imperative. Investigations already referred to and others pointed at once to an almost inexhaustible source in the benzene of the enormous tar accumulations.

The technical methods to which resort was had to meet the requirements of the new manufacture, firmly established the distillation of coal-tar as an industry. Its subsequent growth is intimately identified with that of the artificial organic coloring matters. The manufacture of the colors and the tar distillation are two mutually dependent branches of one great organic chemical industry. The bulk of the world's most valuable tar products is consumed by the color-works, and the raw materials of the latter, as before stated, are supplied chiefly by the tar distilleries. From mauveine these industries have thus proceeded in their development in closely approximating parallel lines, as will be abundantly evidenced in remarks to follow.

The meteoric success of the first of the aniline dyes was soon to be outdone by the more brilliant and lasting career of *fuchsine*, begun in 1859. Like mauveine, an oxidation product of aniline, the manufacture of the new dye-stuff caused a tremendous impetus to the production of aniline, and transmitted it through benzene to the tar distillation.

The classic researches of Hofmann upon the methylation derivatives of fuchsine followed its introduction, increasing the number of artificial dyes and again strongly stimulating in turn the aniline manufacture.

1 Caro: *Ueber d. Entwickelung d. Theerfarben-Industrie*, Ber. d. deutsch. chem. Ges. *25c*, 1029.

The next chapter in the history of the industry opens in 1869 with the synthesis of *alizerine* from derivatives of *anthracene.* This hydrocarbon had long been recognized as present in the last distillates of the tar refineries, but regarded only by the scientist with interest. Now that the artificial preparation of the most highly prized of nature's dyes was an accomplished fact, a great future, with vast and far-reaching commercial and political-economic results, was immediately foreseen for the manufacture. A first effect was the incitement of new activity among the tar distilleries. Anthracene, thus far an utterly worthless substance without technical application, suddenly became an article of great commercial value, and chief among the products of the industry.

In decided contrast with anthracene, occuring sparingly and difficult of separation in pure form, is *naphtalene*, quantitatively the most important chemical individual yet discovered in coal-tar and easily prepared from it in a state of chemical purity. These circumstances naturally caused its early discovery. Notwithstanding it is last among its associates to find extensive use. Hitherto it had been applied, besides to other comparatively trifling purposes, wholly unrelated to the color manufacture, mainly in the manufacture of the eosines of the triphenylmethane series.

In 1876 *chysoïdine*, a coloring matter belonging to the great group of azo-dyes, was introduced. Its appearance was the industrial impetus to a general development of this most prolific as well as one of the most important branches of the artificial dye manufacture. As will be discussed later in detail, naphtalene derivatives soon became of utmost importance in the preparation of azo-colors; their consumption by the industry has attained huge dimensions.

In rough outline, the main features of the progress of the tar distillation have been thus traced. From its crude beginnings in the hands of alchemy, its course has been pursued to the present advanced state of development under the rule of

modern chemistry and chemical technology. Your attention will next be asked to such of its products as are known in the manufacture of the artificial organic coloring matters as

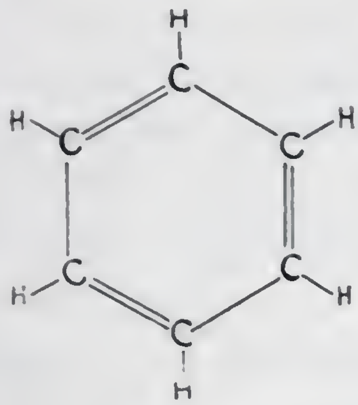
RAW MATERIALS.

The by-product of the gas manufacture from which these substances are prepared is the black, oily, rather viscous fluid of penetrating and peculiar odor, familiar in its general superficial properties almost equally well to the chemist and the uninitiated.

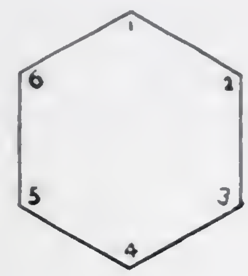
Researches have revealed among its constituents a large number of aromatic organic compounds belonging mainly to the benzene series in the restricted sense of the term. Chief among these are the hydrocarbons, a number of which have just had repeated mention. Compounds of the same series, containing oxygen as well as hydrogen and carbon, are also of importance both in respect to quantity and application. Associated with the benzenes are other aromatic compounds in which nitrogen is characteristic in part. Members of the pyridine series may be mentioned as the most conspicuous. The class of paraffines, co-ordinate with the class of aromatic bodies, is also represented. The last named and the pyridines are wholly insignificant in quantity and technical importance as compared with the benzene derivatives among which are the materials about to be considered.

Before treating of the separation of these substances from the tar, it would seem in place and of advantage to add a few remarks upon their chemical relations. This will perhaps conduce to clearness and evoke the more interest in the subsequent discussion of the separation.

Benzene, to which every other compound of the series bearing its name may be referred as a close chemical relative, has the constitutional formula shown by the following familiar and celebrated atomic arrangement :



or abbreviated,

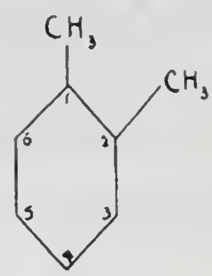


Benzene.

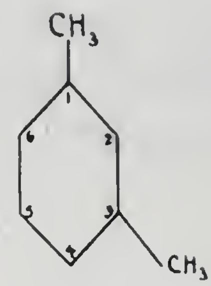
The molecule consists as seen in the formula of six atoms of carbon and an equal number of hydrogen symmetrically united, the lines representing the carbon affinities forming, when continued to intersection, a regular hexagon. Each carbon atom, besides two others of the system, further binds an atom of hydrogen. It will be noticed that the lines of affinity among the carbon atoms are alternately double. This expresses the famous conception of Kekulé concerning the constitution of benzene. As you are well aware, it has been the working model of the organic chemist in the aromatic series almost from the time of its announcement in 1865 to the present; a review of the brilliant successes of the theory would exhibit magnificent advances in pure chemistry and remarkable synthetic achievements as emanating directly from it, but would partake too much of the nature of a digression under present circumstances to be allowable.

Substitution of the hydrogen atoms of the benzene molecule directly or indirectly by various elements, radicals, and rests results in an almost numberless host of compounds, its derivatives, its analogues, and the derivatives of the latter. Those occurring in coal-tar, and which call for mention in this connection, are *toluene*, *the xylenes*, *naphtalene*, and *anthracene* among the hydrocarbons; and *phenol*, oxybenzene, among the oxyhydrocarbons. Their constitutional relations are shown by the following usual and abbreviated formulas:

Toluene.

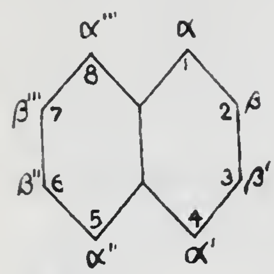


Orthoxylene.

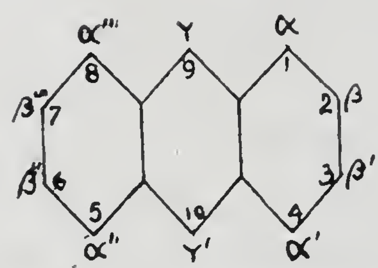


Metaxylene.

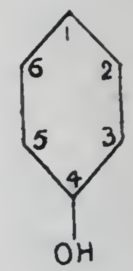
Paraxylene.



Naphtalene.



Anthracene.



Phenol.

The analogues of benzene, naphtalene and anthracene, may also be regarded as its indirect derivatives. Their molecules have been constructed by the use of substituted benzenes, and, as a glance at the formulas will show, are to be conceived in formation as condensations of respectively two and three benzene molecules.

Special attention is requested in passing to the isomeric compounds of the benzene series, arising from a difference in the relative position of the substituents. A simple illustration, found among the formulas reproduced, is that of ortho–(1.2.), para–(1.4.), and meta–(1.3.), xylene, three compounds of the same percentage composition, the same molecular weight, yet of different physical and chemical properties. The number of isomers for a given number of substitutes increases rapidly in progression from benzene to anthracene. A monosubstituted benzene exists in one form only, while the analogous derivatives of naphtalene and anthracene are two and three in number. With two and the same substituents, diderivatives of naphtalene may have ten different forms, while the corresponding anthracenes may be as many as sixteen. Should the entering elements or radicals be two and different, the possible number of isomers is still more augmented.

These facts are no longer merely scientific curiosities, but have, in numerous instances, a most important technical bearing, as will be repeatedly instanced hereafter. This circumstance is the apology for introducing the foregoing familiar, elementary considerations.

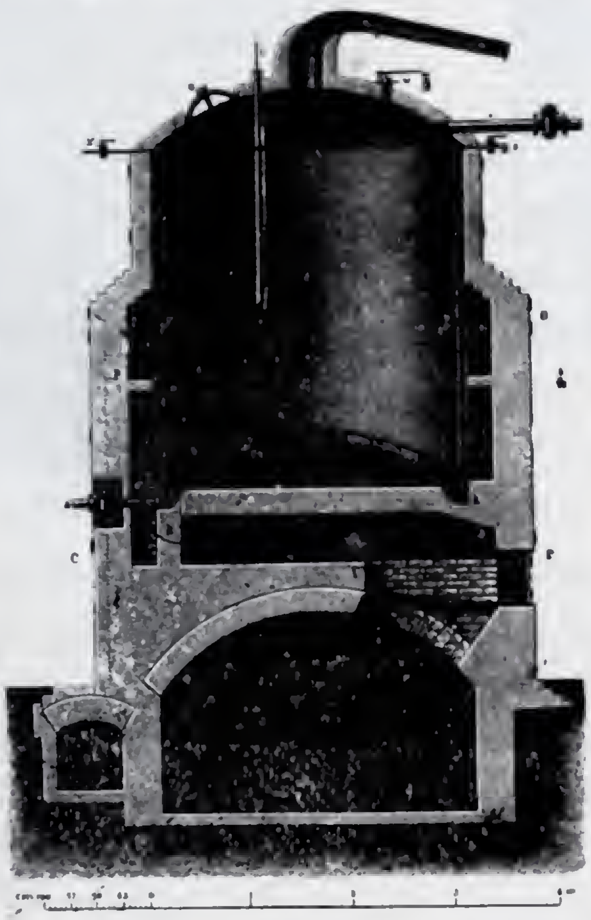


Fig. 2.

From the theory of their nature and relationships, the discussion will be continued to the technology of the production of benzene and its relatives from coal-tar. The first operation to this end is the separation of the tar into several fractions by distillation. The still for this purpose is shown by the accompanying illustration,[1] Fig. 2. This depicts the usual form of tar-still as constructed in England and Germany, the largest producers of crude and refined tar-products. The material is of boiler-plate. The capacity varies from ten to twenty tons in the English works; in Germany, where they are generally larger, they hold a charge of as much as fifty

1 The depictions of Figs. 2, 3, 4, 5, 6, 7 are reproductions from the work of Lunge already quoted: *Die Industrie d. Steinkohlentheers u. Ammoniaks;* those of Figs. 8 and 9, from Harmsen: *Die Fabrikation d. Theerfarbstoffe u. ihrer Rohmaterialien.*

tons. The arrangement and purpose of the parts will be plain without comment. A condenser and receivers, likewise of iron or soft steel, connect with the still and dispose of the vapors and distillates. The details of the distillation, the manner of conducting and regulating it, must be passed over; they would lead, if discussed, beyond the boundary of the immediate object of this review.

The distillates themselves, however, and the subsequent manipulation of them will necessarily be considered somewhat at length.[2] The custom in respect to the fractionation of the tar varies considerably in different distilleries. I shall not burden you by reproducing from the literature series of temperatures and gravities limiting the fractions and showing diversified usages, but have selected a single set of limitations which are authoritative and of more general application. According to these, using a thermometer to guide the operation (the practice of the German works, especially), the fractions of the first distillation are thus defined: FIRST RUNNINGS, from 105°–110°C.; LIGHT OIL to 210°; CARBOLIC OIL to 240°; HEAVY OIL to 270°; and ANTHRACENE OIL above 270°.

Benzene, *toluene* and *higher homologues* of the former, important factors of the color manufacture, are contained in the first runnings together with paraffines, some phenol, ammonia, bases of the pyridine series, and bodies of lesser technical import; and in the light oil.

In order to their separation, the light oil is first redistilled in an apparatus in all respects, except capacity, similar to the stills for the main or first distillation. The first portion of the distillate, up to 120° C., is added to the first runnings, and the residue, after washing successively with caustic soda and sulphuric acid, is returned to the light oil reservoir.

The first runnings, with the 120° fraction of the light oil, are freed from phenol and pyridine bases by agitation, first,

2 Harmsen: *Die Fab. d. Theerfarbstoffe u. ihrer Rohmaterialien*, and Lunge: *Die Ind. d. Steinkohlentheers*, etc., may be compared for full details.

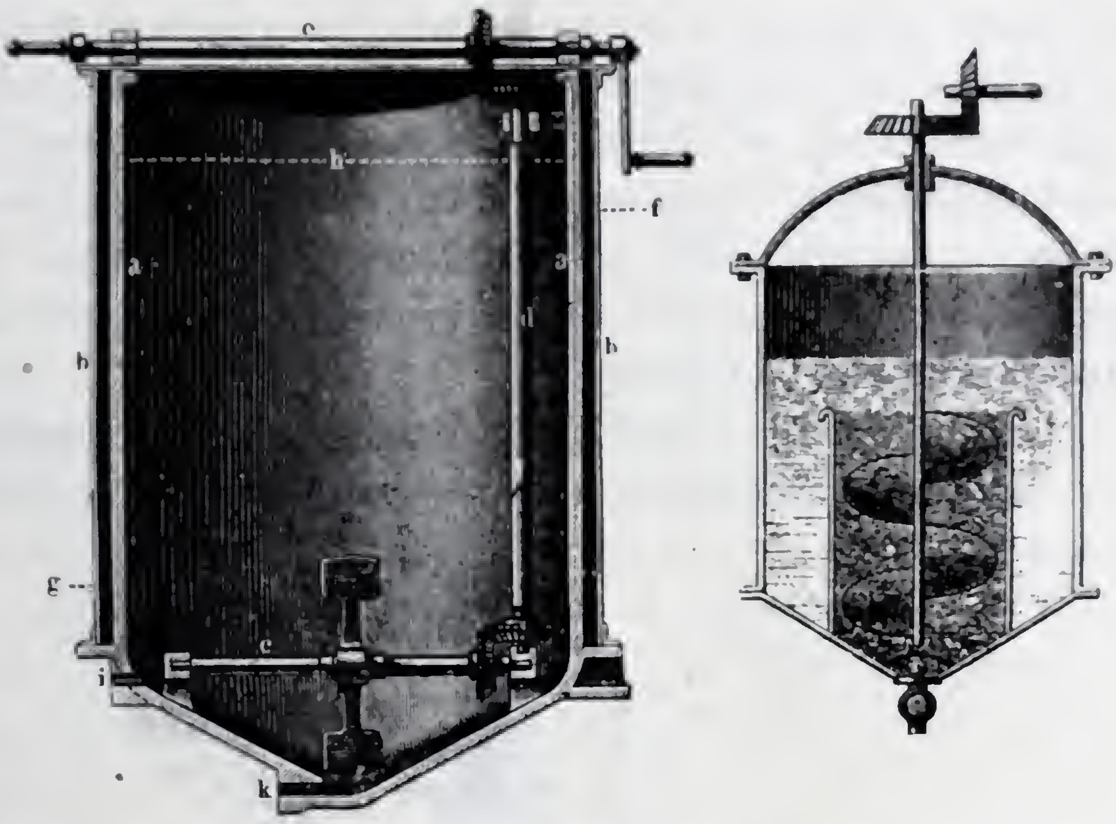


Fig. 3. Agitators for washing light oil.

with caustic soda and then with sulphuric acid, after the manner of the second fraction of the light oil, and in turn undergo rectification. This is effected in an apparatus represented by Fig. 4. Heat is always applied by means of the steam-coil. The vapors issuing from the still are required to pass a reflux

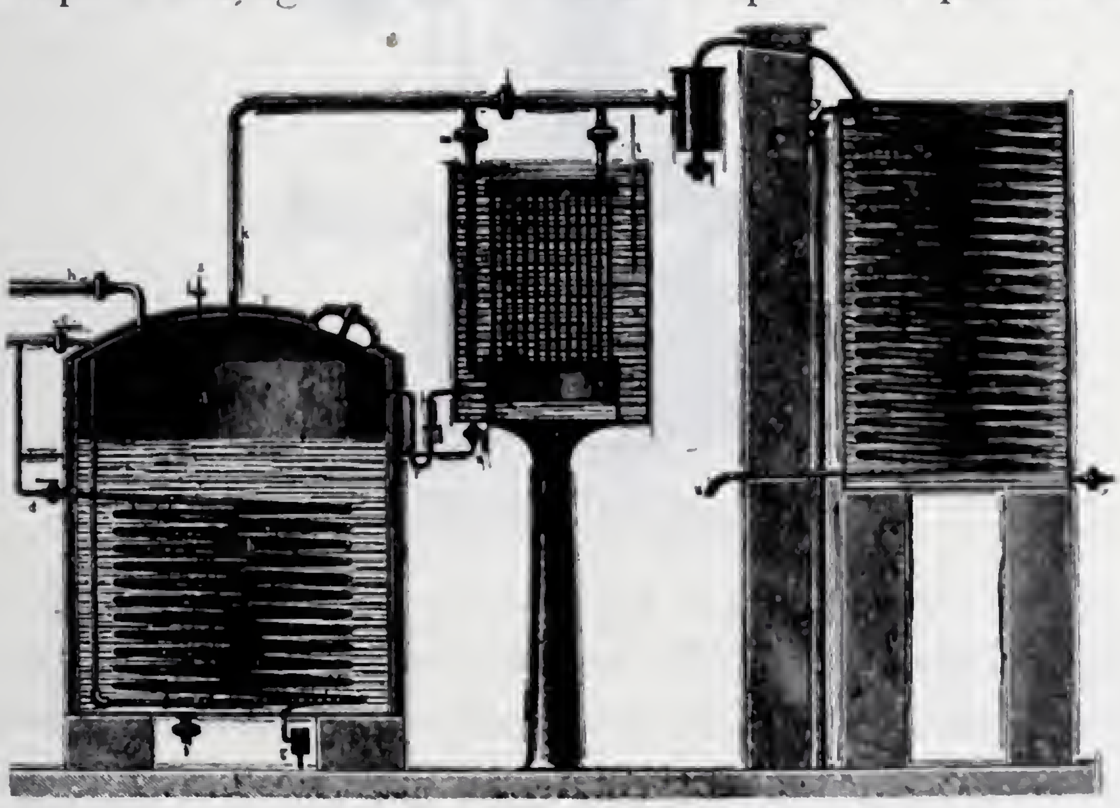


Fig. 4.

system kept by the surrounding water at varying temperatures in accordance with the nature of the desired product. Here the vapors from oils of higher boiling-point are condensed and returned to the still. The more volatile bodies pass on to the condenser. As intimated, the character of the latter may obviously be varied by a corresponding regulation of the temperature in the partial condenser.

The results of this distillation form the current grades of crude commercial benzene, mixtures principally of benzene, toluene and xylene.

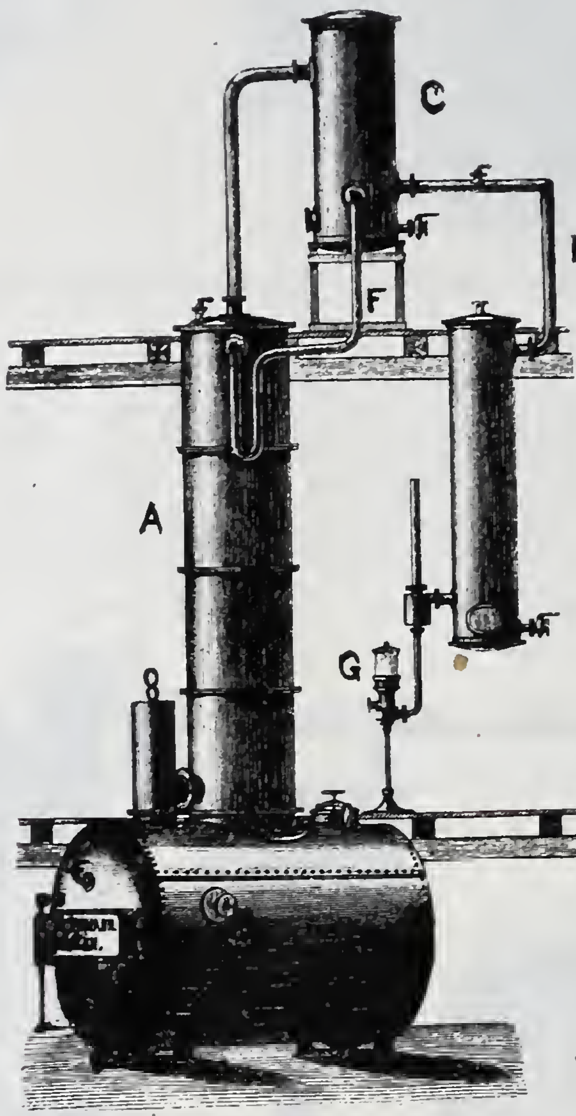


Fig. 5.

When required in a high degree of purity, as is the case in the manufacture of pure aniline, the preparation of benzyl-chloride, benzaldehyde, benzoic acid, etc., benzene and toluene are separated from crude benzene in the apparatus universally used for the technical fractionation of the more volatile liquids.

Originally designed by Savalle, as you may recall, for the rectification of spirits, it is now familiarly known to the technologist by the name of the inventor as a "savalle." In Fig. 5 a general view of the still is presented. With all appurtenances it extends nearly to the top of the tall building containing it. The column or analyzer rises like a great tower to a formidable height. The top of the column connects with the upper end of the partial condenser *C* in which is a set of vertical parallel tubes. These are joined, for vapor, with the cooler through *E* from which the distillates flow; and, for fluids, connect with the top of the column by means of the pipe *F*. A stream of water, surrounding the tubes and regulated with reference to the contents of the still and the purpose of the rectification, opposes in direction that of the vapors.

Fig. 6.

The interior of the analyzer, *A*, is exhibited by Fig. 6. The space enclosed is partitioned by a series of horizontal plates or diaphragms uniformly disposed throughout its length. Each diaphragm is perforated and has a cylindrical depression into

which dips the overflow tube of the diaphragm next above. The upper end of the tube projects perhaps two inches beyond the diaphragm. The remainder of the apparatus serves the purposes of the similar parts of Fig. 4.

It may not be amiss to reflect for a moment upon the analytical action of this most efficient of all arrangements for fractional distillation. The mixture of vapors to be analyzed, as it ascends from the still, passes the first of the lower plates but soon condenses in part, forming a fluid layer consisting mainly of the components of higher boiling-point and increasing in depth until the level of the overflow is reached. At this point a reflux of the liquid toward the still is begun through the tubes. The vapor pressure from below prevents a return by way of the fine perforations. Through these, however, the uninterruptedly rising vapors may advance. In passing they heat the fluid upon the diaphragm, causing a deposition of part of their contents and partially volatilizing the fluid already condensed upon the diaphragm. The uncondensed fraction and the newly vaporized portion proceed together to the diaphragm above where the same process is repeated. The most volatile constituents of the mixture in the still are therefore constantly approaching the top of the column while those of higher boiling-point are tending downward. On each diaphragm a fractional distillation is in progress. The completeness of the analysis is directly proportional to the number of diaphragms.

The distillates flowing from the condensers, at certain stages of the distillation determined by laboratory examinations, are almost absolutely pure benzene and toluene. From the still-residues, the xylenes, principally *meta-xylene*, may be obtained.

Phenol, carbolic acid, is prepared from the distillate above designated as carbolic oil. The procedure in the hands of different manufacturers varies greatly in details which belong to the imagined secrets of the works. Essentially it consists in

the extraction of the oil with caustic soda solution, separation of the carbolic acid from the resulting phenolate by decomposition with a mineral acid, and purification of the crude phenol by fractional distillation.

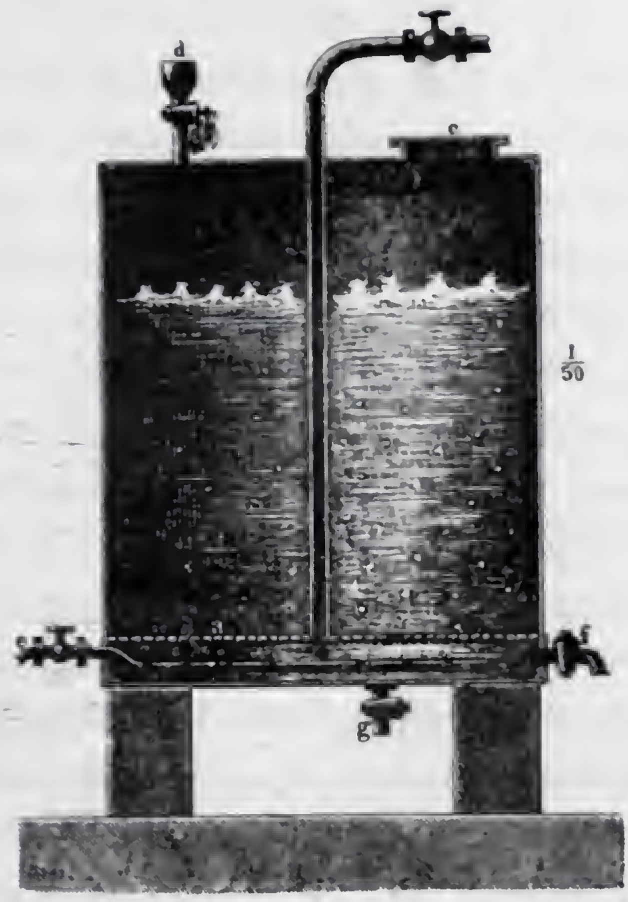


Fig. 7.

The extraction is effected in an apparatus of which a notion will be given by Fig. 7. It is one of the numerous forms of stirring machines for unmiscible fluids, a covered iron tank with compressed air attachment, the pipe *b* which ends in a perforated distributing disk *a*. Near the bottom, below the disk, a steam-coil provides the necessary heat. The mixture of the carbolic oil with a dilute solution of caustic soda is agitated vigorously in the tank several hours at a temperature approximating 40°C. The quantity of soda solution required is determined by a laboratory experiment with the oil under treatment. After the stirring, the contents are allowed to stand at rest until the aqueous solution and the residual oil have separated. In the course of a few hours the latter has collected, forming the upper of the two layers. The lower, the alkaline

extract, has a very appreciable solvent action upon the hydrocarbons present with phenol. Impeding or rendering the purification almost impossible, their removal is imperative. This is effectively accomplished by a method suggested by Häussermann,[1] and based upon the volatility of the hydrocarbons in a current of steam. The phenolate solution is accordingly drawn off at *g* into an iron still and steam passed through it until the distillate runs clear. It is further purified by agitation with air. A quantity of tarry materials is precipitated. These are removed and the solution, together with the alkaline washings from the light oil, is acidified by sulphuric or carbonic acid in a lead-lined vat. Phenol and its homologues are set free and collect as an oil above the sulphate or carbonate mother-liquors. The oil is transferred to a still from which it is divided into three fractions. From the second of the three, phenol crystallizes in an almost pure form. After thorough removal of the mother-liquor, first by decanting and then by use of the centrifugal machine, the crystals are redistilled and yield a brand of phenol meeting the more severe requirements of its application.

Carbolic oil from which phenol has been removed is the chief source of *naphtalene.* The distillation of this residue produces, besides fractions which are added to the light oil and heavy oil, a large middle distillate which rapidly solidifies to a more or less white crystalline mass slightly admixed with the oils in which it occurs. These are expressed in a warm hydraulic press. The crude naphtalene obtained is washed in a tank, similar to those shown for use with light oil, with sulphuric acid. It is then sublimed or distilled; as being more compact, distilled naphtalene is preferred in the main by the color-works to the sublimed product. Both preparations have the objectional property of reddening to a certain extent on long exposure to the air. On the supposition that the coloring is due to the oxidation of impurities (phenol possibly) Lunge[2]

1. Lunge: *Steinkohlentheer;* p. 324.
2. Lunge: Ber. d. deutsch. Chem. Ges. 14, 1755.

proposed the addition of a small quantity manganese peroxide, in the form of "manganese mud," to the washed naphtalene when distilling it. Thus prepared it may be kept for years without coloration.

Anthracene, as before stated, the most valuable of the coal-tar products, is contained in the last distillate of the main tar distillation, a greenish, slightly fluorescent, oily conglomeration of almost pasty consistence. The removal from the distillate, in which it is present as a crystalline suspension, is begun by passage through the filter-press. The crude material from the filter is subjected to high pressure in the heated hydraulic press. The adhering oils are thereby almost completely removed. The cakes from the press are a heterogenous mixture in which anthracene, phenanthrene, carbazol quantitatively and otherwise predominate. To separate anthracene from the mass, its great insolubility is utilized. Digestion with solvent naphta (fractions of high boiling-point from the first runnings) or petroleum naphta, boiling at 80–100°C., dissolves the hydrocarbons, except anthracene, and leaves a residue with about 50% of the latter. Extraction with pyridine bases decreases the impurities of crude anthracene to 20% and less. By distillation with steam a further slight purification and fine subdivision of the product may be effected. In this form anthracene is employed for the preparation of pure anthraquinone, the initial transformation in the process of its conversion into alizerine.

A few statements with reference to the quantitative results of the distillation should be made before dismissing the subject. The tar itself is of inconstant composition, depending both upon the nature of the coal from which it is derived and the conditions of its formation. The composition of the distillates will therefore show corresponding differences, and will be influenced also by the manner of their own preparation. A review of the question would be inconsistent with the plan before me and cannot be undertaken. I append simply a sum-

mary[1] of what may be regarded as an average of results and wholly serving present requirements. The main constituent of coal-tar in point of quantity is the pitch which is contained to the amount of 50 to 60 %. The remainder consists principally of oils and ammonia water. The largest product of the distillation among the oils is the heavy oil. It comprises 25 to 30 % of the tar. Of the constituents just discussed, the yield of benzene and toluene is 1 to $1\frac{1}{2}$ %; carbolic acid (pure), .4 to .5 %; homologues of phenol, 2 to 3 %; naphtalene, 6 to 10 %; anthracene, .25 to .45 %.

INTERMEDIATE PRODUCTS.

With the exception of phenol, none of the products separated from the coal-tar distillates is applicable directly as synthetic material in the manufacture of the artificial coloring matters. It is as derivatives, intermediate products of the industry between the raw materials and the dye-stuffs, that each is applied. It will therefore be necessary to first consider some of the more important of these substances before undertaking a discussion of the colors themselves. Their manufacture involves principally the use of reactions which are distinctively characteristic of the aromatic series, and particularly of benzene and its derivatives.

Foremost in importance among them is the familiar process of nitration or the substitution of hydrogen by the nitro-group,—NO_2; the reduction of the nitro-group with the formation of amido-derivatives containing the group of atoms, —NH_2; the transformation of the latter into a peculiar and highly reactive combination, —N=N—, or diazotation; and the process of sulphonation by which hydrogen is eliminated and replaced by the sulphonic group, —SO_2-OH. Besides to the preparations yielded by these reactions, reference to certain oxygen and halogen compounds of greatest technical importance will be demanded.

1 Meyer u. Jacobson: *Lehrb. d. organ. Chemie*, II., 93.

NITRO-DERIVATIVES. The largest quantity of benzene, toluene, and naphtalene consumed by the color manufacture is by far that which first undergoes the process of nitration. The reaction :

$$R\text{-}H + HO\text{-}NO_2 = R\text{-}NO_2 + H_2O$$

in which R is an aromatic radical, is so well known that it is given only for the sake of completeness. The technical operation consists in treating the hydrocarbon or a derivative with concentrated nitric and sulphuric acids.

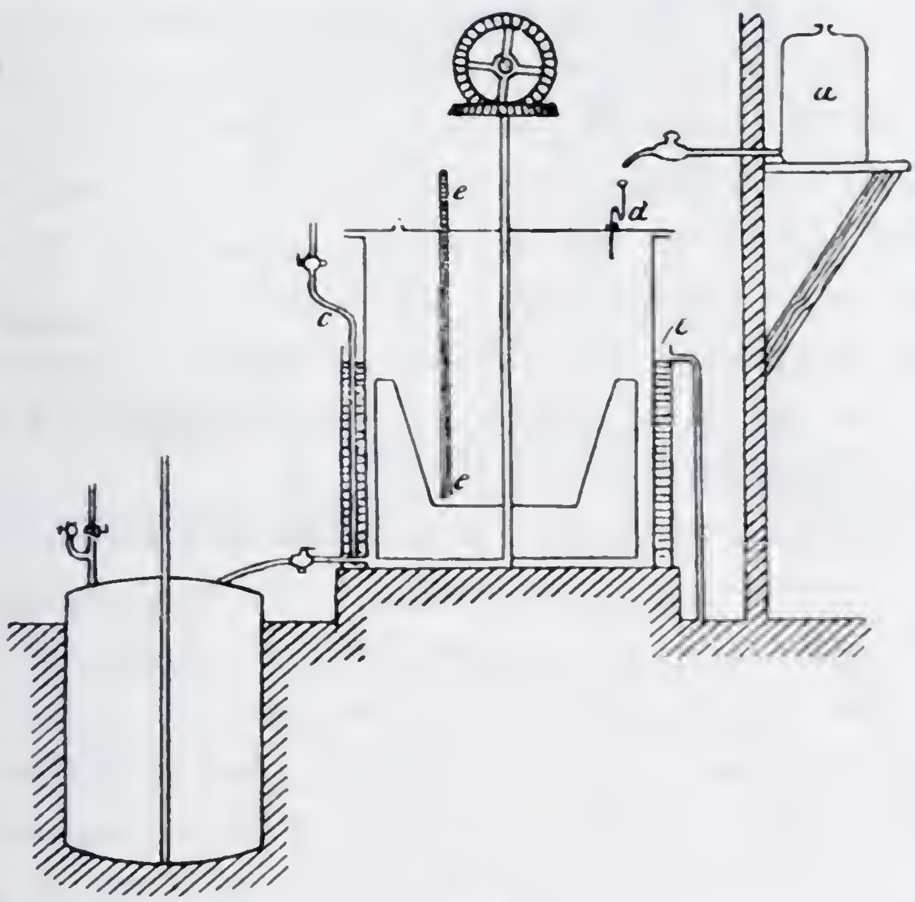


Fig. 8.

The outline sketch will convey in sufficient detail an idea of the construction of the technical apparatus made use of in nitration, particularly of benzene. In the center of the drawing may be seen the cylinder in which the reaction takes place. It is of cast-iron, has a mechanical stirrer, thermometer, and jacket for the control of the temperature. In an elevated position is an earthenware vessel, the reservoir for the acid mixture. Below the cylinder is a so-called montejus.

For *nitrobenzene*, charges of about 200 lbs. are worked. This quantity is run into the cylinder, the jacket filled with cold water, and the acids slowly added from the reservoir in which they are contained in the ratio of one part by weight of nitric to one and four-tenths of sulphuric. The former has a specific gravity of about 1.40; the latter of 1.845. In all about 500 lbs. of the mixture are required for the above charge. The addition takes place during eight to ten hours, the temperature being carefully held at about 25°C. Later, toward the end of the operation, it is raised to 50°C. The stirring is continued several hours after the acid is all in. The contents of the cylinder are then lowered into the monte-jus from which compressed air elevates it to a great separating funnel (not shown in the drawing), a cast-iron cylinder with conical bottom. The "nitro" and acid here are given opportunity to separate, the former collecting above the acid. Drawing off the latter, washing and rectifying the nitro complete the process.

The nitration of toluene is throughout a similar operation. The same may be said of naphtalene, with the modification that the reaction requires a temperature approximating 100° C.

Nitrobenzene and its homologues and *nitronaphtalene* have their main application not as such but after reduction to

AMIDO-DERIVATIVES. First in rank among these bodies are *aniline* and *toluidine* which are manufactured to the extent of thousands of tons[1] annually. Aniline is the universal reagent of the color-works.

The preparation of this remarkable substance cannot fail to be of interest. The reaction of the aniline converter is expressed in its simplest form by the equation:

$$C_6H_5NO_2+3H_2=C_6H_5NH_2+2H_2O.$$

It was first carried out by Zinin with NH_4HS as a reducing agent. Béchamp[1] was the author of the use of nascent hydrogen as generated by the action of acid on iron filings. The

1 Caro: *Ueber d. Entw. d. Theerfarbstoffe*, Ber. d. deutsch. chem. Ges. *25c*, 989.

acetic acid used by him was later replaced economically by hydrochloric acid; thus modified, it is the industrial method of the present.

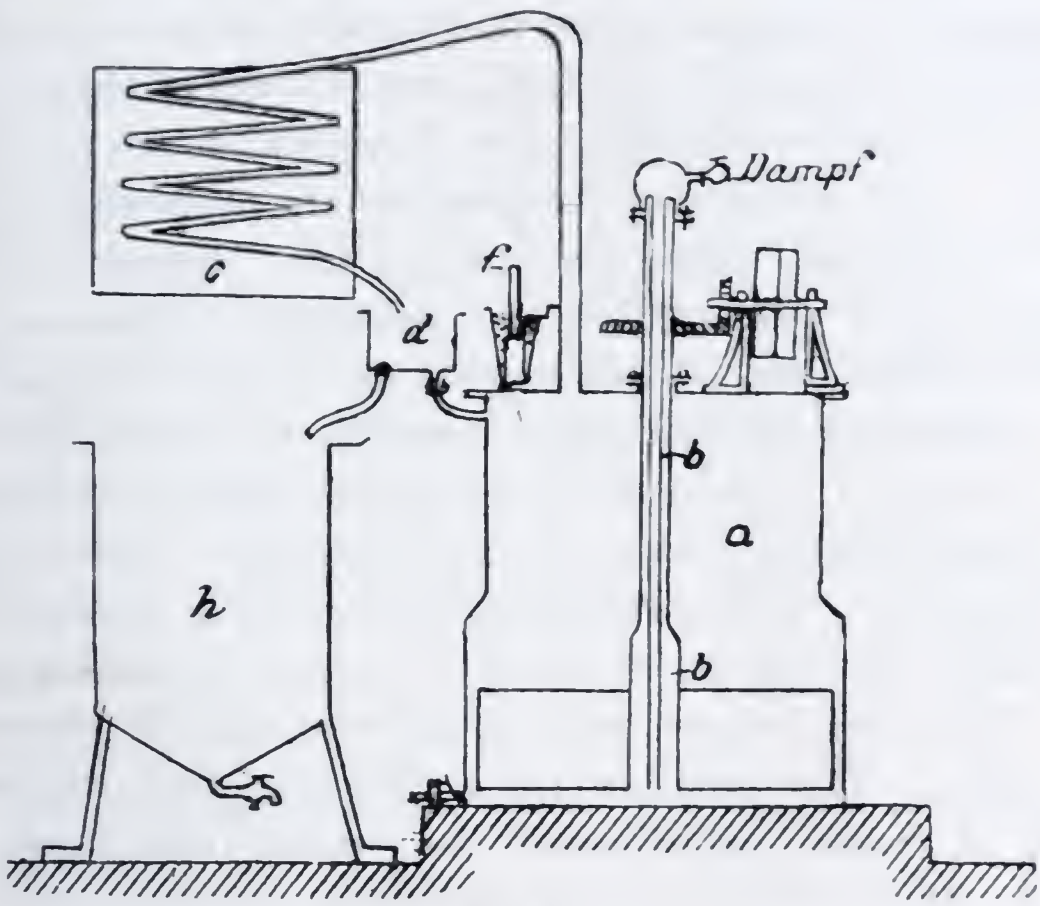


Fig. 9.

The drawing, Fig. 9, adequately indicates the mechanical means adopted for its execution. A, the reduction chamber, is of cast-iron and capable of holding a charge of 1500—2000 lbs. of nitrobenzene. In general equipment, it resembles the cylinder for nitrations. It differs in having a stirrer with hollow axle through which steam may be introduced. At *f* a capacious funnel is represented. It communicates with the chamber and is closed with a wooden plug. A reflux condenser connects the chamber with an ordinary condenser, and, through the basin *d*, with the reservoir *h*.

In operating the nitrobenzene with an admixture of water is brought into the cylinder and heated with steam to boiling. Hydrochloric acid of 1.17 sp. gr., in amount about four per cent. of the charge of nitro, is added, and the steam cut off. Through the funnel finely ground cast-iron is introduced in

small portions. A lively reaction begins, but is allowed to moderate before further additions of iron. The aim throughout is to maintain a steady and moderate rate of reduction. Seven to eight hours elapse before the whole of the iron has passed the funnel. In weight it somewhat exceeds that of the nitrobenzene. A colorless distillate gives evidence of the end of the reaction. The contents of the chamber are made alkaline with milk of lime, and steam again turned on. Vapors of aniline and water pass together into the condenser and thence to the reservoir where the aniline collects as an oil underneath the water. The not inconsiderable quantity of aniline dissolved by the water is recovered by using the latter to supply the boiler generating the steam for the distillation following the next reduction. In the rectifying still the oil is separated into fractions of varying purity, some of which have their special uses. The most impure are worked over again in succeeding distillations. The purity of the aniline from the reducer will depend, of course, upon that of the benzene from which it is derived. If it contain toluene, toluidine will be a constituent of the reduction product.

Two well-defined varieties of benzene are placed upon the market by the tar distilleries, one the so-called 50% benzene, "benzene for red," and a 90% brand, also known as "benzene for blue." This distinction is carried over to the amido-derivatives, that from the first being used in the fuchsine fusion and the others in the manufacture of aniline blue. Another mixture of the bases, aniline and toluidine, consists almost entirely of aniline and orthtoluidine, and is a by-product of the fuchsine manufacture. A fourth species is a mixture of ortho- and paratoluidine. From it the individual bases are separated and applied, or, mixed with aniline, used as "red oil" in the manner just indicated.

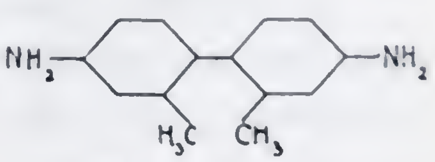
Other amido-derivatives, of importance from their relation to the azo-branch of the dye-stuff industry, call at least for mention in this connection. *Metadiamidobenzene*, in its prepara-

tion entirely analogous to aniline, is a prominent instance. From alphanitronaphtalene, already named among the nitro-derivatives, *alphaamidonaphtalene* is prepared by the now familiar method of Béchamp. Isomeric with this amine is *betaamidonaphtalene* or betanaphtylamine. It is obtained, however, by a totally different method dependent upon the action of ammonia upon betanaphtol.

Benzidine and *toluidine*, of great moment in the synthesis of a numerous group of coloring matters of peculiar qualities, must also be mentioned as intermediate products of the amido-type. They are derivatives of diphenyl; their constitution is expressed in the formulas which follow:

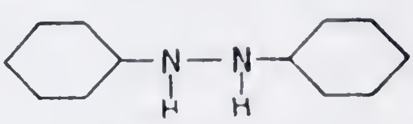

Diphenyl.

Benzidine.



Orthotolidine.

When nitrobenzene is reduced by zinc and caustic soda, hydrazobenzene:



results. Subjected to the action of hydrochloric acid in boiling solution, hydrazobenzene undergoes an intramolecular change to the isomeric benzidine:

$$C_6H_5NH\text{-}NHC_6H_5 + 2HCl = HCl\ H_2NC_6H_4\text{-}C_6H_4NH_2\ HCl.$$

The reactivity of the hydrogen atoms of the amido-group has given rise by substitution of the radicals methyl, $—CH_3$, ethyl, $—C_2H_5$, phenyl, $—C_6H_5$, and others to a highly important class of compounds. Especially should *dimethyl-*, *phenyl-*, *benzylaniline*, and *similar derivatives of naphtalene* be noted. Time will permit further mere mention of the value of such modifications in the manufacture of dye-stuffs.

A principal application of the products of amidation occurs in the manufacture of the azo-colors, where they are consumed in enormous quantities, chiefly after transformation into

DIAZO-COMPOUNDS. A discussion of the preparation and application of these bodies would comprehend that of the above manufacture itself. This having been reserved for special treatment in another connection, diazotation may be dismissed with reference to it purely as a reaction. When an amido-derivative is exposed to the action of nitrous acid in the cold, its amido-group undergoes a change indicated thus:

$$R\text{-}NH_2+NO\text{-}OH=R\text{-}N:N\text{-}OH+H_2O,$$

R again being the radical of the amido-compound.

A group of substances of exceeding importance should next have attention. I refer to the

SULPHONIC ACID DERIVATIVES. Those most extensively employed are produced from amido-derivatives of benzene and naphtalene, and the oxynaphtalenes. Especially the compounds of naphtalene figure with marked prominence. The numerous sulphonic acids of alpha- and betanaphtylamine and the corresponding naphtols are synthetic materials unsurpassed in importance in the dye-stuff industry.

As to the preparation of the sulphonic acids, remarks need only extend to a few general statements in respect to the principles of the technical methods. The technology of the subject may be deferred to a later occasion, the description of the alizerine manufacture, when it will be amply illustrated.

The direct action of concentrated sulphuric acid and of fuming acid with varying percentages of sulphuric anhydride, under modified conditions of quantity of acid, time, and temperature, is the main process for the introduction of one or more sulphonic acid groups; the more energetic action producing the more highly sulphonated substances. The simple, general equation added is an expression for the reaction:

$$R\text{-}H+HO\text{-}SO_2\text{-}OH=R\text{-}SO_2\text{-}OH+H_2O.$$

A special process applied in the manufacture of the most important of the monosulphonic acids of aniline and alpanaphtylamine, *sulphanilic* and *naphthionic* acids, is based upon the

behavior of the acid sulphates of these amines at a temperature of 200 to 250°C. The reaction concerned is represented in the following equation in the case of aniline:

$$C_6H_5NH_2 \text{-} H_2SO_4 = C_6H_4 < \begin{matrix} NH_2 \\ SO_2OH \end{matrix} + H_2O.$$

Sulphonated amines are also prepared by the reduction of the corresponding nitro-compounds. *Metanilic acid*, meta-amidobenzenemonosulphonic acid, is made on this principle from nitrobenzene.

Besides directly, the products of sulphonation are further applied intermediately in the preparation of the

OXY-DERIVATIVES. Heated with caustic alkali, the sulphonates react in the well-known manner with the formation of alkali sulphite and an oxy-compound of the radical with which the sulphonic group was united. The reaction in detail will be plain from the appended equation:

$$R\text{-}SO_2\text{-}OH + 2NaOH = R\text{-}OH + Na_2SO_3 + H_2O.$$

This is the basis of the now famous method of Kekulé for the substitution of the sulphonic group for hydroxyl. By means of it, the first synthetic phenol was obtained. It has since accomplished a number of the most signal successes in the manufacture of the artificial colors. It began its career with what is still its greatest achievement, an economic solution of the great industrial problem of the conversion of anthraquinone into its dioxy-derivative, alizerine.

The *naphtols* and certain of *their mono-* and *disulphonic acids*, isomeric with those made by the direct sulphonation of alpha- and betanaphtol and products of prime importance, are results of its application. The acids are prepared by a partial elimination of the sulphonic groups in the di- and trisulphonic acids of naphtalene.

The manufacture of *resorcine*, metadioxybenzene, essential to the preparation of the splendid fluoresceïnes, again pointedly illustrates the importance of the process.

The amido-group, through the medium diazotation, affords

a further means of preparing oxy-derivatives. Diazo-compounds, formed as already indicated from amido-compounds, when heated with water decompose in the familiar manner shown by the equation :

$$R\text{-}N : N\text{-}Cl + HOH = R\text{-}OH + N_2 + HCl.$$

Naphtolmonosulphonic acids, differing from those prepared by methods already cited and of special technical worth, have been derived by this method. A notable instance is furnished by *alphanaphtolmonosulphonic acid 1.4* from naphthionic acid.

In conclusion a few remarks will be added in respect to certain

Chlorine-Derivatives. Of lesser importance than the reactions already dealt with, chlorination is nevertheless a valuable auxiliary operation in the preparation of a number of extensively consumed intermediate products of the dye-stuff manufacture. Those obtained from toluene and phtalic anhydride, $C_6H_4 < {CO \atop CO} > O$, should be especially emphasized.

Toluene when treated with chlorine, according to the conditions, may be made to yield *benzylchloride*, $C_6H_5CH_2Cl$, *benzalchloride*, $C_6H_5CH_2Cl$, and *benzotrichloride*, $C_6H_5CCl_3$. Benzylchloride is used in introducing into certain molecular complexes the radical benzyl, $C_6H_5CH_2$—, a reaction to which reference has been made. The other chlorides are converted respectively into *benzaldehyde* and *benzoic acid*, both, but in particular the former, are valued industrial materials.

A mention of the *di-* and *tetrachlorphtalic acids* and their use with striking colorific effects in the manufacture of the phloxines must suffice.

The numerous modifications of the hydrocarbons extricated from the black smear of the gas-works by the operations of which a glimpse has been presented in the foregoing discussion constitute a great aggregate of chemical individuals enhanced in a sort of potential energy in the form of new qualities, expressions of a modified molecular structure. Thereby

they have become adapted to use, under the influence of chemical affinity guided by modern methods, in the synthesis of compounds of remarkable properties. The new substances are *colored*, are empowered in great diversity to annul a certain component of incident light to which they may be exposed. The emitted complements, the colors of the substances, when white light is concerned, are of corresponding variety and complacent rivals of the shades of the solar spectrum. Furthermore, an essential of the compounds in mind is the power to *impart color* to organized matter, not by mere adhesion, but *by a species of firm incorporation*.

The transformation of the intermediate products before you into coloring matters, materials characterized by the above qualities, will be the subject of immediately succeeding paragraphs.

THIRD REPORT OF COMMITTEE ON ROADS.

Pennsylvania has the worst roads in having scarcely anywhere system in amendment of the first pioneer ways, nor definite provision for the permanent improvement of the quality of them.

The State and toll highways did have some advantage in alignment with reference to the needs of their day—but the proposition of the turnpike companies to build on three-degree grade being as open to departure as the five-degree of the common road—there was less as to gradient; and all have decayed together under the township care in working out the road taxes.

The condition of the roads just beyond the State's boundaries has been for decades more tolerable; south of us the vogue of letting for a year mile sections of the district (township) road has fixed the responsibility, aroused pride, and so evoked the personal element for the good of the community. There are some townships in Pennsylvania that have the like results under the special act passed in 1865 for Lower Merion in Montgomery Co., one of these is our Leet township.

Over the line in Ohio they have had local pikes for years which are improved roads made by assessment on bordering properties in a belt a mile or two wide, the railroad property in the right of way being assessed with the rest.

Our former Committee on Roads we find outside of the transactions published a pamphlet as a final report containing a revised law for offer to the legislature of 1891. This is elaborate and smooth under a legal hand; defines highways as roads between populous places and to shipping points; states that 30 per cent. of the State's tax from corporations shall go into the highway fund; anticipates the use of the roadways by passenger railway companies, etc., in prescribing conditions as to exhibit of their maps of precise location, bonds for care in

construction of railway, telegraph, etc., and thus permits the taking of part of the road. It has the following in parenthesis: ("In locating or changing roads he shall get the easiest grades and the most direct alignment consistent with a reasonable cost of construction and maintenance, and without too great damages to the land through which the road is located, but no location shall be adopted without the approval of the county engineer or his deputy"). We miss here the simple, rugged virtues commended by us and in the discussion, but there is no doubt that neither gradient, alignment, damage to private property, nor cost of construction or maintenance either, should absolutely rule or have assigned weight or orderly position of importance, if we are considering streets or local roads; but should in deciding upon highways.

The general road laws we see are antiquated or impracticable for betterment, except the live Flinn road law, especially made for converting here into county roads the township roads radiating from the city's suburbs, these being already connected by paved avenues. The two mill tax collected under this law in Allegheny county for the two years amounts to $343,000, of which $90,000 has been already expended.

Mr. F. W. Patterson, the county road engineer states here: "The transforming of the bad roads of this mountainous county into good roads has been under way only a few months and as a result ten miles are in successful operation. Briefly stated, the plan adopted for getting them into shape for improvement is as follows: Complete surveys were made, exact levels and cross sections taken each fifty feet and the topography of the ground for a distance of 500 feet (and further where deemed necessary) to the right or left of the road at all points where it appeared possible to make a change of location that would enable us to reduce the gradient. At all such places with few exceptions, we met with much opposition from the land owners to any change of location; in some instances exorbitant prices were asked for only a few feet of

land ; one case only will be cited for illustration : Mrs. Smith, who resides at the top of the 'Butler Road Hill,' demanded $800 for 560 square feet of land of which the actual value is $1,000 per acre. The ten miles have been improved, reconstructed and partially relocated in a practical way. The prevailing tendency to shorten distance in going to a point, that would urge crossing over the ravine and tunneling the hill is the one extreme, while the other for the purpose of securing a minimum gradient would take a circuitous, winding course and perhaps double the length of the road. The method at present pursued has some of the features of the two plans without going to extremes, involving a minimum outlay with it is believed the maximum of good results.

"The farmers who can now transport their produce with a saving of from 30 to 40 per cent., disregard the cry of failure heard from the disgruntled. To so great an extent is the slope or grade of a road dependent upon its direction or rather upon the locality which it traverses, that direction and grade appear almost inseparable. While the desire and intention is to lower the (in many instances) excessively heavy grades of 12 to 15 per cent. to a maximum of seven or eight per cent., yet owing to reasons previously given, not to speak of political influences, which sometimes weigh very heavily in the balance, desire and intention has in more than one instance been defeated. The topographical features of Greater Pittsburg, so well known, it is submitted do not permit drawing the line at one-eighteenth, or say a little over five per cent., as some engineers would for the maximum, without involving expenditures unwarranted under the circumstances of the case.

"No new road, however, should be built having a grade much in excess of five per cent. and should be governed, First, by its two termini as to general direction ; second, by the best gradients that can be obtained beween their two points without great damage to private property ; third, by the sacrifice of distance in order to obtain easiness of grade ; fourth,

by ever keeping before one the fact that directness of route must be subordinate to easiness of grade with economy in both cases; fifth, by meeting all the interested or adjacent property owners, listening to their suggestions, weighing them justly and applying them in so far as they coincide with the principles of good road location and are free from bias and neighborly jealousies.

"But the improvement of old, steep roads along which cozy homes of modern type, with level entrances obtained by terracing and retaining walls, alternate with others at the level of the road, give trouble. Say in the case of a valley running north requiring a location on either hillside to ease the grade in reaching the summit, all land owners adjoining the old road have joined in petition. One man will give you a release if his property has not been touched; another, if you consent to keep the road entirely on his poperty so he can charge his neighbors good stiff prices for rights-of-way across a small neck of his land to the improved road; another will grant you a release rather than see his neighbor benefited; another, if you will place the road where he wants it, as *he* has visions of a city surrounding him and has a town site mapped out with himself located on the public square, so you must put the road upon one of his streets in order to save him the expense of vacation proceedings in the dim future. These and countless others are the reasons why location and relocation are so 'pleasantly and easily made in Western Pennsylvania.' It is difficult to instill into the mind of the average rural inhabitant that 'every judicious improvement in the establishment of roads and bridges increases the value of land, enhances the regularity of the price of commodities in the market and augments public wealth.'

"Contrary to assertions made that improved roads have grades of 10 or 12 in the hundred, let it be definitely understood, we have only one case of nine feet in a hundred as the highest permitted to be used and not adopted until all efforts

to effect a change of location to better the grade had been rendered ineffectual by the combined opposition of the property owners adjacent. This being on the Butler Pike, where there existed a grade of 14 feet in the hundred for a considerable distance. Other instances on same road are thirteen lowered to seven, and eleven to six; other grades being comparatively light."

We understand what may be expected in trying to make good grades on the old lines that were laid out trying for five degrees but permitting greater steepness.

It has to be a good horse to take 800 pounds on clay road or 1,000 pounds on macadam surface up five degrees, whereas on five per cent. he could take 1,000 pounds or 1,600 pounds, and on the level can haul 2,000 pounds or 5,000 pounds.

All over Europe the good roads building era was a century ago, the railroad building afterwards and slower than here (because of their good roads there shall we say?) where its great spread in the new country actually retarded the getting of good highways as they depended on other than local aid.

In those days of heavy freighting overland by team it was a rule in Austria to require extra horses used for ascending hills with rise exceeding 1 in 24, and an inn at the foot had as one of its reasons for being, the furnishing of such extra power up the hill.

As regards relation between quality of the surface and grades, railroads find even ten feet per mile an obstacle to heavy freight trains, and five per cent. is the very limit for friction traction locomotive to haul anything. The flat steel road track now advocated to have practicable easiest animal propulsion as well as traction on wagon way, would not be so advantageously available down long steep grade as up.

The more improved the surface is to favor draft, the less in a measure may it depart from a level grade.

The result of observations and experiments by Samuel T. Neely, Asst. Engineer Office of Road Inquiry, show: That the draft on a dirt road is two and a half times as much as on a macadam road.

That it seems to require from six to eight times as much force to start a wagon as to keep it in motion afterwards. The tractive force for a dirt road is 100 pounds more or less per ton. For a good macadam road it was found by test to be 38 pounds (equal to that for block pavement) and for asphalt pavement in poor condition 26 pounds.

He quotes that the force of traction varies universally as the diameter of a wheel; and that this force increases with the speed upon hard roads, but not in proportion to velocity. Also that the width of tires is found to have no effect on the traction on hard roads, but it has a very decided effect on the condition of the road surface and its maintenance.

Thompson, the inventor of the pneumatic tire 50 years ago (as a leather hose with an inner tube of rubber), proved by test that tractive force on macadam road with it was but six-tenths of that with iron tire.

The effect of grade is to add to the tractive force on the level a proportion of the weight of the load in the ratio of the rise to the distance.

Thus 1 per cent. grade adds 20 pounds per ton, making for macadam the force $38+20=58$ pounds per ton, and for 2 per cent. 78 pounds which as compared with the 38 pounds on the level shows the equivalent length of level road to be 2.05 times. A five per cent. macadam road requires 138 pounds per ton draft and this power for one mile of it is equal to 3.63 miles on the level road. For a dirt road at the rate of 100 pounds per ton on the level the requirement for five per cent. grade would be 200 pounds, and 2 miles of level road the equivalent of 1 mile on the grade.

In the newer states because of freer public opinion the roads and highways both can be discriminatingly new-made

and kept under local authority, recognizing competent technical executive ability to propose the best lines and construction. But in the older states it is different, because there is so considerable a change of what is established involved.

Montana claims its road law, approved March 4, 1897, as the pioneer one for the whole country, making county surveyors superintendents of all roads in their respective counties.

Massachusetts made its first appropriation to a State Highway Commission in 1894 of $300,000; and in 1895 of $400,000, in 1896 of $500,000 and in 1807 $800,000. The amount is to be used at the discretion of the Commission the ensuing year. "The policy has been not to allow a random construction of isolated stretches of road but to make the construction of all ways fit a general scheme for a system of thoroughfares traversing the state."

Procedure according to the Act of 1894 is as follows: The selectmen of any town (township including villages), the aldermen of any city, or the county commissioners must file a petition with the Highway Commissioners, accompanied by a plan and profile of the road. Plans are then prepared by the chief engineer of the Highway Commission and submitted for its approval.

"A part of the settled policy is to reduce all grades to a maximum of five per cent." After plotting the courses (bearings and distances), and obtaining data for determining the quantity of various materials used in construction of a road, a conference is held between the petitioners and the State Commissioners, in order to ascertain if a contract for the construction of the road is to be made by the municipality, and, if so, at what price it is to be done. In case the city or town authorities are unwilling to contract for the work upon the prices agreed, the commission advertises the same, and it is let to the lowest responsible bidder, subject to the approval of the Governor and Council. It is the custom in awarding competitive contracts to require the contractor to furnish bonds: one

insuring a faithful completion of the work; the other to safeguard the interests of town or city in case damage results from accidents during the building of the way. "The Commission appoints a resident engineer, who has personal charge, subject only to the supervision of the chief engineer."

We learn from General Roy Stone: "The most noticeable and extended co-operative work has been done in New Jersey, under the State aid law of 1891. Under this law the property owners along any line of road are assessed 10 per cent. of the cost, and in addition to this the State contributes one-third of the total, and the county is compelled to furnish the remainder and to construct the road. This law has been so effective that the appropriation has been almost annually increased and the demand for construction under it has many times exceeded the funds available. It has, moreover, created competition for the benefits of State expenditure, and in that way has promoted discussion and education in regard to road improvement more rapidly than any other system."

"That the State of Massachusetts has adopted a different system is probably due mainly to the non-agricultural character of the State. There it is necessary that roads be built to connect manufacturing towns and districts where the property along their lines is of little value for agricuture and the interests of the Commonwealth is independent of any agricultural conditions. The State has therefore taken upon itself the entire burden of building the principal roads throughout the Commonwealth, though it ultimately requires the counties to pay one-fourth the cost."

In grading for a highway, the drainage being a prime requisite there should be embanking rather than cutting. In this section of the country it is unsafe along a steep hillside to attempt balancing the quantities; the toe of an old slip cut into on the upper side gives rain and frost a chance to make it slide, and also to disintegrate and dislodge rock that in place

may seem at first capable of standing with steeper face of slope than will dry earth. A wall can hardly be built in on upper side that will hold still their exposed face.

On the winter side of the hill—not the choice aspect for a location—the safe roadbed on precipitous ground would be a causeway altogether above the natural surface, upheld by retaining wall well founded (deeper than for ordinary structures where exposure at the bottom would be less), and the walls may require a thickness equal to half their height.